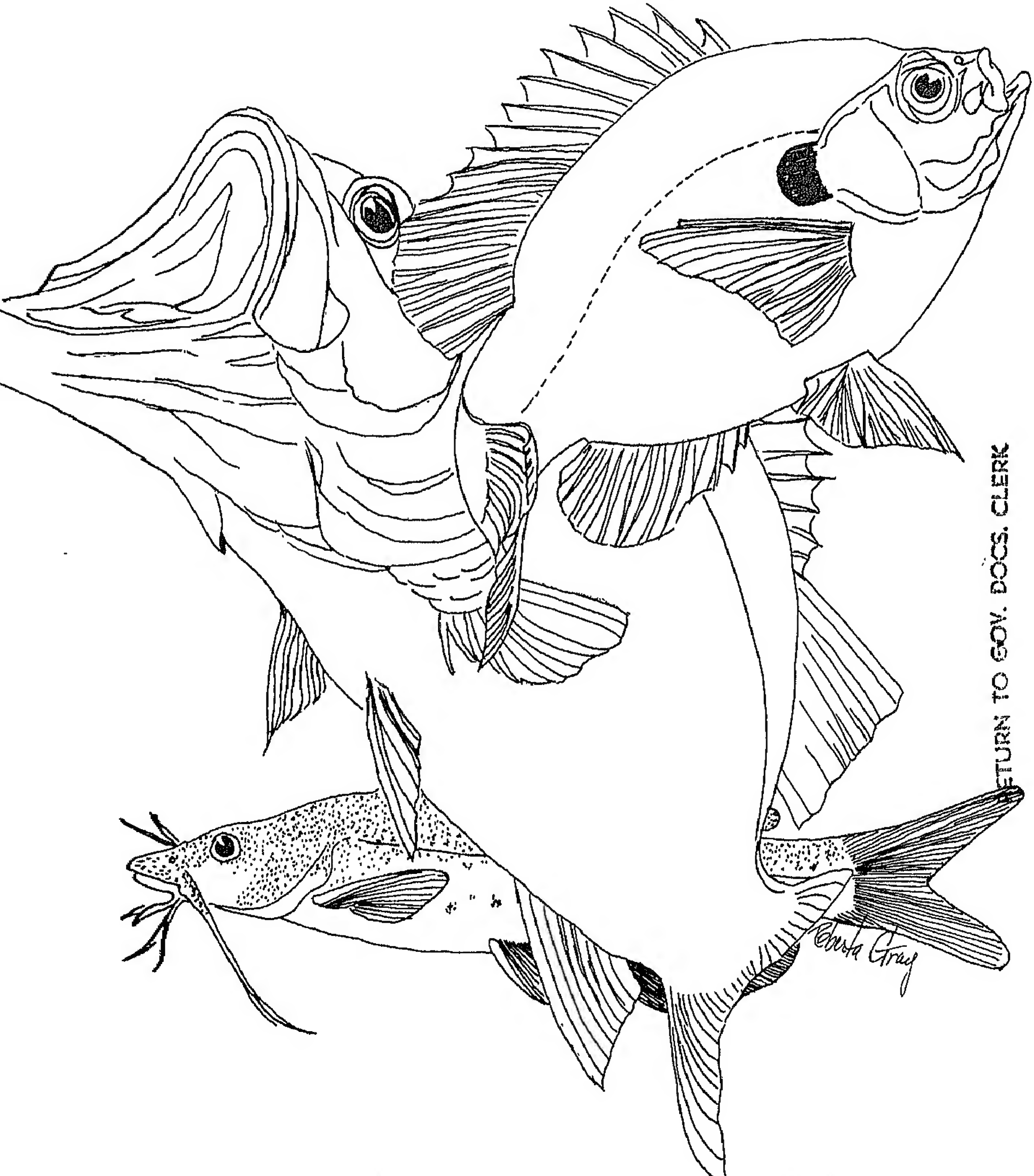
Pond Management for Sport Fishing in Arkansas



POND MANAGEMENT FOR SPORT FISHING IN ARKANSAS

BY

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SOIL CONSERVATION SERVICE

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INTRODUCTION

Arkansas had about 119,600 farm ponds in 1978, covering approximately 97,100 acres, in addition to about 830 ponds (32,700 acres) in commercial food and baitfish production, and 160 ponds (5,700 acres) devoted to fee fishing. These farm ponds range in size from less than 0.25 acre to 10 acres. The average pond in Arkansas is less than 0.50 acre and more than 90 percent are less than one acre.

These ponds represent a valuable fishing resource, which if properly developed, can bring quality fishing to virtually all fishermen in the state. But good pond fishing doesn't just happen. It takes more than creating a pond, stocking fish, and waiting. Every pond owner interested in fishing should realize that fish are a crop and a pond is like a crop field -- it must be managed to provide good harvests.

That's what the following information is all about -- managing ponds to develop and maintain healthy fish populations and good fishing.

SITE SELECTION

Selection of a good pond site is an essential first step and should consider the following topics.

Size of Pond

If bass and bluegill are to be stocked, the pond should be at least one acre in surface area when full. Smaller ponds are more difficult to manage for extended periods for several reasons. Their fish populations tend to be less stable since any changes is fish numbers constitute a greater percentage of the total fish population than in larger ponds. Aquatic plants become more of a problem because of their increased interference with recreation in the smaller body of water. These plants also contribute to overpopulation and stunting by providing cover for smaller fish. Summer and winter fish kills are more frequent in small ponds because they are often shallow. Small ponds can seldom support enough fishing pressure to make management worthwhile, and they are more apt to go dry or provide unsuitable conditions during droughts. These negative characteristics may require that smaller ponds be restocked occasionally.

Arkansas ponds must be at least 0.25 acre in area in order to receive fish from the U.S. Fish and Wildlife Service. If the pond size is much less than one acre, channel catfish should be stocked. However, small pond owners who still wish to have bass and bluegills in their ponds should realize the limitations of their ponds and be prepared to manage them carefully and in a timely manner.

Source of Water

Enough spring flow, well water, or silt-free runoff should be available to fill the pond in a year or less and to replenish water lost

by evaporation and seepage. Where runoff is the source, the amount of watershed needed may vary from a ratio of 3 to 20 acres for each acre of pond. The soil, amount and kind of vegetation in the watershed, and the slope of the land determine the watershed ratio needed. Rainfall runoff is greater from pastureland than from woodland, and therefore, a smaller watershed ratio is required for a pond in a pasture than would be needed for a pond of equal size in a wooded area.

Watersheds which are cultivated or otherwise lack sufficient vegetation are undesirable sources of pond water because of the rapid rate of runoff which carries large quantities of sediments. Too much water also washes out nutrients which reduces productivity, and may even result in loss of fish or the dam.

Ponds built on streams which flow most of the time usually have excessive overflows. Such ponds cannot be fertilized economically, and the costs of eliminating stream fishes from the pond are often prohibitive.

Soil and Topography

Soil at the site should contain enough clay to prevent excessive seepage from the pond bottom and from the dam. Also, the pH and lime requirements of the soil should be examined and corrective measures taken as needed.

The topography of the area should be suitable for the economical construction of a pond with the desired surface area. Locating pond sites in areas where the relief is too steep or too flat will naturally result in undesirable quantities of runoff.

Access

Consideration should be given to location of the pond and access roads in relation to the home. Pond management not only will be easier, but is more apt to occur when ponds are located near the home or when an all-weather road provides access to the pond.

Time to Build

The completion date should be considered when the pond is planned. Early fall is the best time for completion of the dam and filling the pond. Sunfish and catfish are available from the hatcheries during this period and stocking them at this time, before the bass stocking, will allow good survival.

Also, lower water temperatures during the fall prevent reproduction of native fish that might be present in the watershed or in the pond basin. Ponds that are completed in the summer usually present the greatest problem in management. Native fish will often reproduce in the pond before hatchery fish are stocked, thus reducing the survival of the game fish. Further, if the pond does not fill promptly, regrowth of brush and trees may fill the pond basin, requiring a second cutting.

If the pond is completed in the spring or early summer, the pond owner should either:

a. not allow the pond to fill until it is time to stock, or

b. rotenone the pond before stocking, if filled by early summer.

Water Depth

A depth of six feet or more should be maintained in at least one-fourth of the pond. Even more depth may be needed to prevent ponds from freezing solid in colder climates, to compensate for seepage and evaporation in run-off ponds, and to prevent very high temperatures during summer.

Shallow water (less than two feet) creates problems in ponds because it encourages the establishment of undesirable aquatic plants which protect small fish from predation. Shallow water and the resultant plants will also provide mosquito breeding areas. Excavating edges of pond banks and other shallow areas of the pond so water is at least three feet deep will help to prevent these problems. The deeper edges also allow the larger predators to stay near the shoreline, encouraging a better harvest of the game fish.

There are three methods for creating deeper pond edges: (1) remove soils from the shallow water area and place them on the outside edge of the pond, (2) place soil from the shallows in the deeper portions of the pond, (3) pile soil excavated from the shallows to make earthen piers (peninsulas). These are very desirable for bank fishermen since they increase the shoreline and improve access to pond areas out from the normal shoreline.

Clearing the Site

The pond should be cleared of most trees and brush. An abundance of vegetation will prevent an adequate harvest of game fish. Stumps and snags especially should be removed from what will be the shallow portions

of the pond. This will facilitate seining which may be needed for proper management of the pond. A 30- to 50-foot wide area around the pond from which trees and brush have been cleared will reduce leaves that fall into the pond. Decaying leaves can cause oxygen depletion in the water. Leaves also encourage growth of filamentous algae and discolor the water.

Removal of trees from the windward side of the pond will allow the wind to blow floating plants, such as duckweeds, to the leeward side and will increase dissolved oxygen through increased wave action.

However, the landowner may wish to save at least some of the trees near the pond for landscaping, shade, and wildlife.

Clearing around the pond will facilitate maintenance of the herbaceous vegetation which should be mowed periodically for the convenience of the fishermen. A good sod cover is needed around the pond to control erosion and sedimentation, but the height of the vegetation within 20 feet of the water's edge should be kept low enough to allow easy access to the entire shoreline.

Core Trench

An earthen dam must have a clay core to seal the subsoil to the above ground portion of the dam. This clay core should extend to the top of the dam to help prevent excessive seepage and loss of water.

The trench should extend at least 3 feet into desirable subsoil. Its width should be about twice its estimated depth at any point and should contain the best available clay.

Drainpipe and Overflow Pipe

It should be possible to completely drain the pond in 5 to 10 days. A pond drainpipe and valve at least four inches in diameter is recommended. The water level can then be lowered in the summer or fall to reduce overpopulation of small fish, for dredging the pond basin when sedimentation is excessive, to drain the pond when undesirable fish are present, or to help control vegetation.

An overflow pipe or trickle tube attached to the drainpipe will keep the normal water level a few inches below the spillway. This reduces erosion of the spillway and prevents drowning of its grass cover. This pipe also helps prevent excessive loss of fingerlings when the pond is first stocked.

Diagrams on the following pages show designs of devices to take outflow from near the pond bottom rather than the top. Advantages for doing this include:

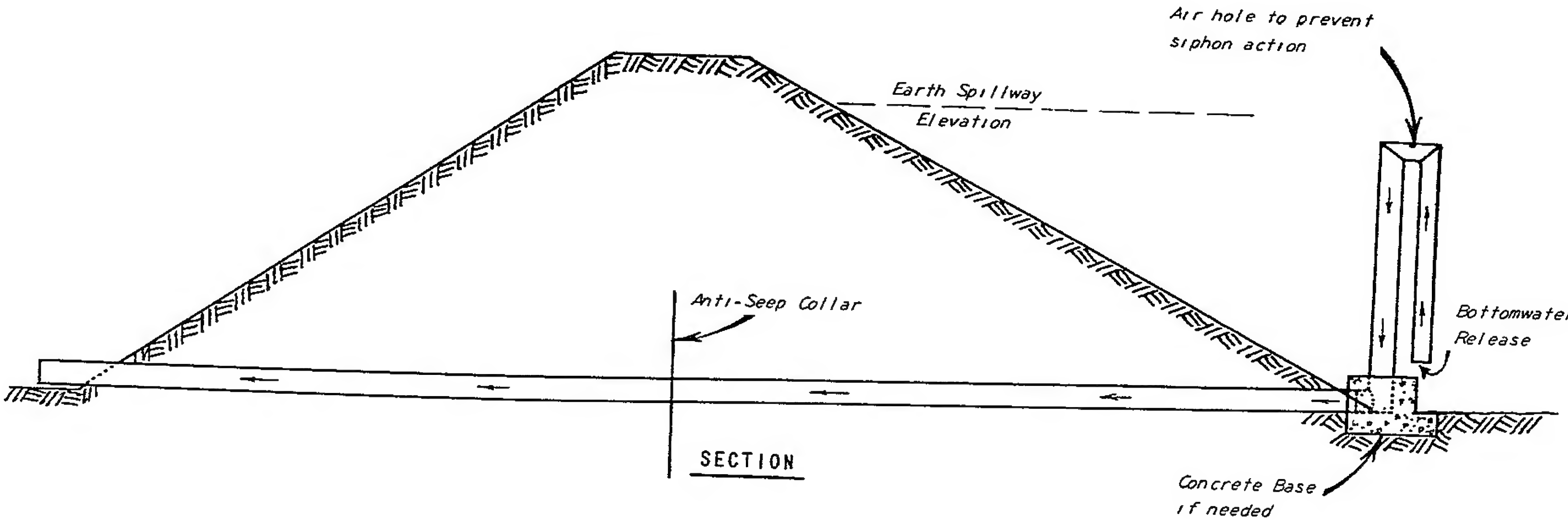
1. Allows surface water temperatures to warm earlier in the spring and remain warmer later in the fall. This increases the growing season. Water temperatures also remain more consistent from top to bottom, thus reducing the probability of thermal stratification which can lead to oxygen depletion in bottom waters.

2. Production of fish food organisms is increased by increasing the depth of the fertile, top layer of water where most of the nutrients

are located and can be utilized. Since it is not going down the drain, this layer stays available for the growth of plankton. However, this layer still is limited by depth of light penetration on which the plankton depend.

3. The water being removed is lowest in oxygen and highest in undesirable gases, provided the device is installed at the correct depth. This will help to reduce the danger of fish kills due to oxygen shortages by reducing the amount of pond water with very low oxygen levels.

4. May help to reduce muddiness of water.



NOTES:

1. To drain pond plug air hole in riser pipe to permit siphon operation.
2. To offset buoyancy effect on light weight riser use 1 C.F. of concrete base for each 1.5 C.F. of main riser volume.
3. Support bottom water release pipe on concrete base if needed.
4. Place inlet about 2 feet from bottom of pond.

FIGURE 1

FISH POND-BOTTOMWATER RELEASE

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, Little Rock, Arkansas

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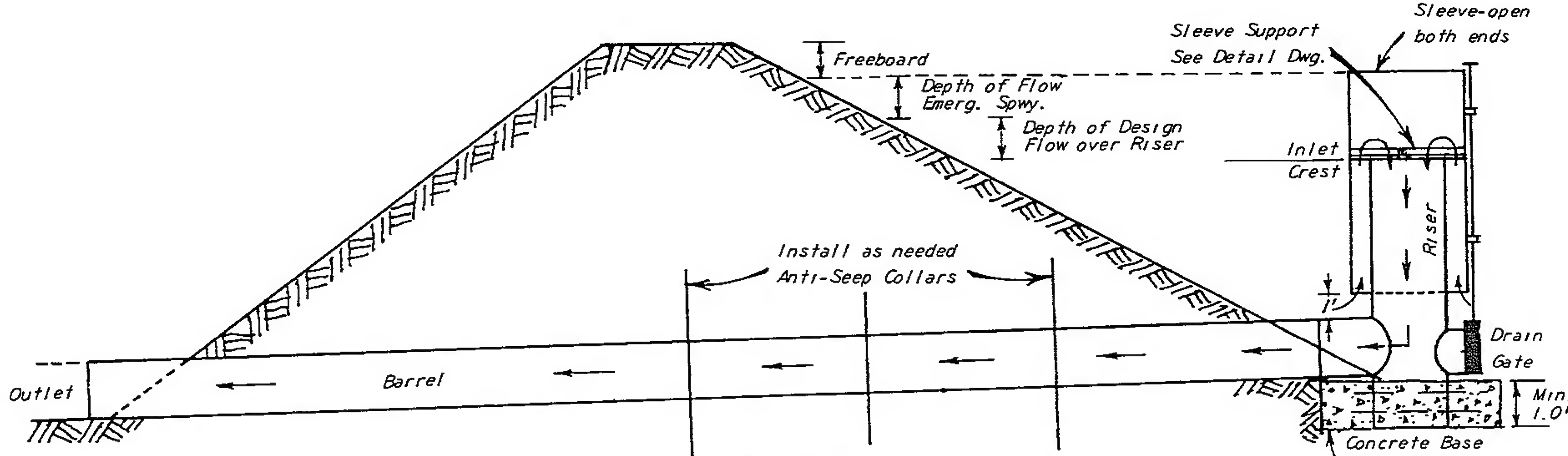

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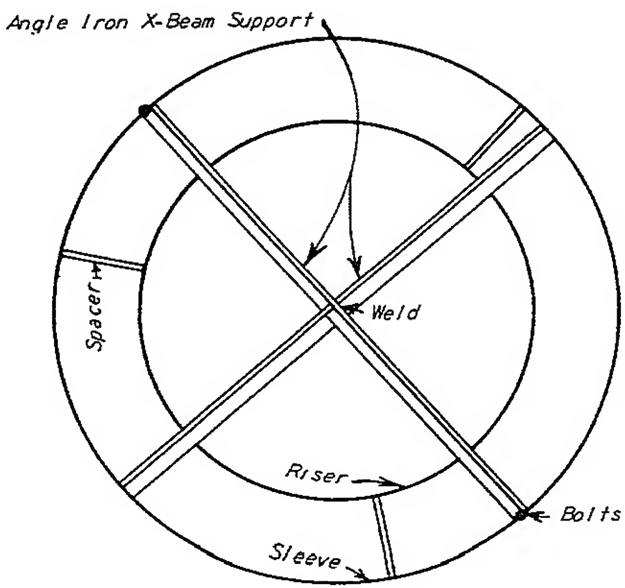

SLEEVE SUPPORT DETAILS

NOTES:

1. Use watertight band couplers.
2. Shop weld nipples to riser for installation of barrel and gate.
3. If only one anti-seep collar is used, locate at ℄ of dam.
4. Where riser and sleeve are small diameter pipe the sleeve may be supported with steel rods rather than angle iron.
5. Use a minimum of three spacer bars near the bottom of the sleeve.
6. Use drain gate with capacity to drain the pond in a reasonable period of time.
7. To offset buoyancy effect on riser use 1 C.F. of concrete footing for each 1.5 C.F. of riser volume.
8. The diameter of the sleeve should be at least 1.5 times the diameter of the riser.

FIGURE 2

FISH POND-BOTTOMWATER RELEASE

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, Little Rock, Arkansas 1-65 4-L-19694-2 of 7

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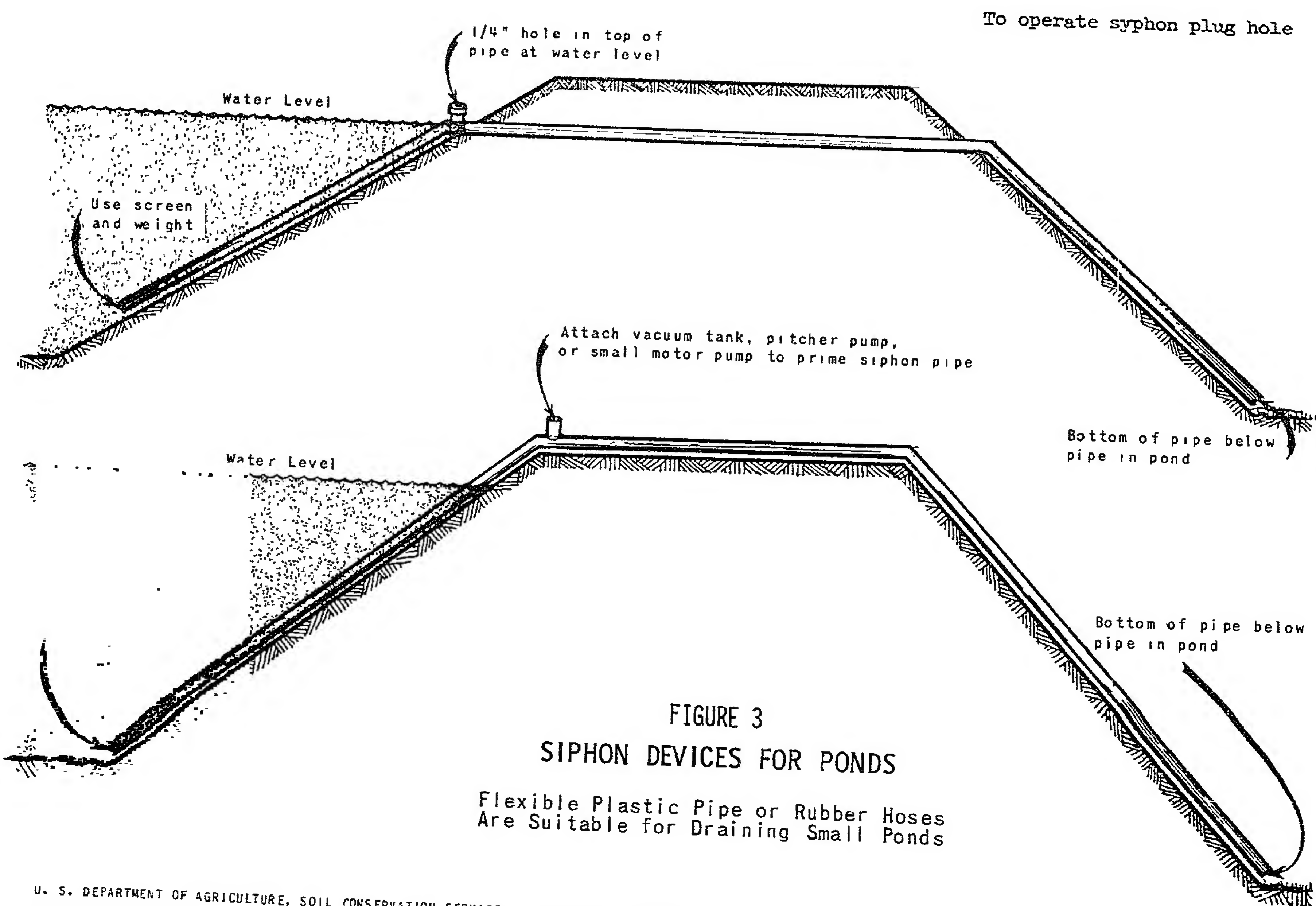

FIGURE 3

SIPHON DEVICES FOR PONDS

Flexible Plastic Pipe or Rubber Hoses Are Suitable for Draining Small Ponds

U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, Little Rock, Arkansas

USDA-SCS-FORT WORTH TEX 1966

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Dam

Well-compacted clay of good quality should be used to construct dams which impound water less than 15 feet deep. Dams which impound water more than 15 feet deep must have porous material in the downstream slope to provide drainage and prevent the build-up of water pressure which leads to sloughing. The top width of the dam should be at least 10 feet. This will help to prevent serious damage from muskrats, nutria, and other burrowing mammals. The dam should be wider if it is to serve as a road.

Spillway

The emergency spillway for preventing floodwater from flowing over the dam should be wide enough to prevent depth of overflow from exceeding 6 inches. This will prevent excessive numbers of fish from leaving the pond.

The spillway should not be screened to keep fish in the pond, since the screen will trap debris. This may cause floodwater to flow over it and endanger the dam. If a standpipe is used to release excess water, the top of the pipe should be 6 inches below the spillway level.

A fish barrier may be constructed in the spillway to prevent the entrance of wild fish during periods of overflow. The barrier should consist of a waterfall with a drop of at least three feet. The fall should have a lip or overhang so that water actually falls through the air for several feet. If the water runs down a slope or even a vertical wall, fish may still enter the pond. Ideally, the spillway should be wide enough to spread the water into thin sheets, allowing only a few inches of water to overflow. The wider the fall the shorter the distance the water needs to drop. This will also help conserve soil in the spillway since thin layers of water are less erosive than deeper layers.

Fish Shelters

The potentials for game fish harvest can be increased by clearing trees and brush and selectively placing fish shelters in the pond basin. In this manner, fish are then concentrated in areas easily located by fishermen, thus increasing the possibilities for larger harvests.

Trees, brush, rocks and other cover provide important areas where fish can hide from predators, rest, find food, and spawn (especially channel catfish). Where natural material is not readily available, fish attractors are often a successful method of creating artificial fish habitat. Fish attractors include any manmade structure placed in water to improve fish habitat. Attractors are for concentrating fishes, while acting as substitutes for natural cover.

Brush or automobile tires provide the most economical and effective fish attractors. These materials are easy to obtain and usually do not require heavy equipment for placement. Rubble, cement blocks, and concrete pipes have been used effectively, but are uncommon and usually not available.

Whenever automobile tires are used, they should be ventilated by slitting or drilling holes in four places. An excellent shelter is

formed by three automobile tires, tied together in a triangular shape which remains upright when anchored with weights. Very good cover is also created by sinking large trees from which the tops have been removed.

Good brush shelters can be made with any underbrush or tree. Oaks, hickories, and cedars are especially good since they are long lasting. Brush can be bound with nylon rope or plastic banding and then sunk with rocks or concrete blocks. Another method is to construct a frame box with two by fours, pack it with limbs and branches and sink it with rocks or concrete blocks.

These shelters should be placed relatively close to shore so they can be easily fished around. A variety of depths and locations around the pond could be used for shelters and evaluated for effectiveness. The most effective ones could be enlarged, perhaps with material from the least effective ones. All submerged shelters should be marked with buoys for the convenience of fishermen, boaters, and seiners.

The following three pages show examples of effective designs for fish shelters in ponds or lakes. These are from the pamphlet "Fish Habitat Improvement in Reservoirs," published by Texas Parks and Wildlife Department, Austin, Texas.

All fish shelters which are visible from shore should be constructed of wood and arranged in ways which are aesthetically pleasing.

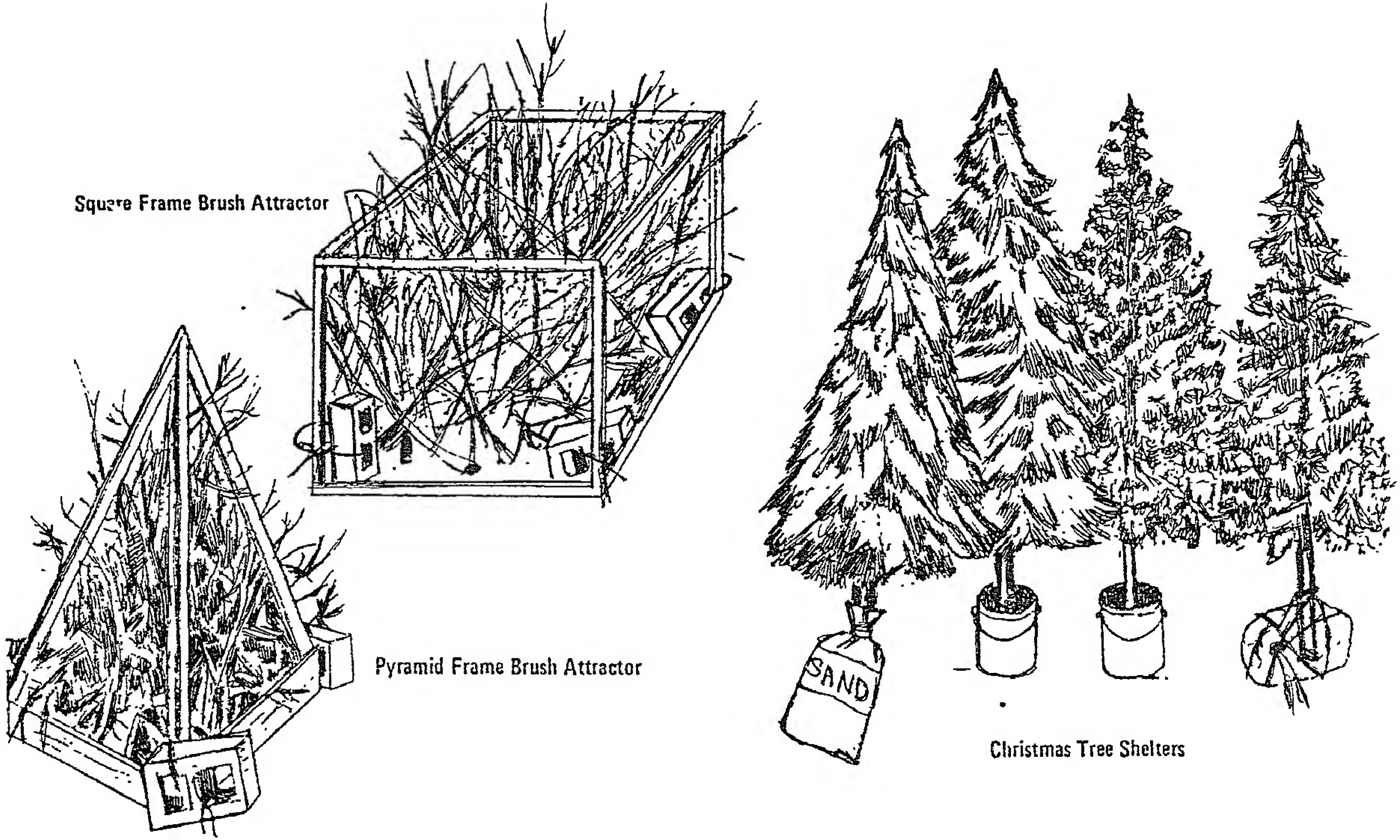
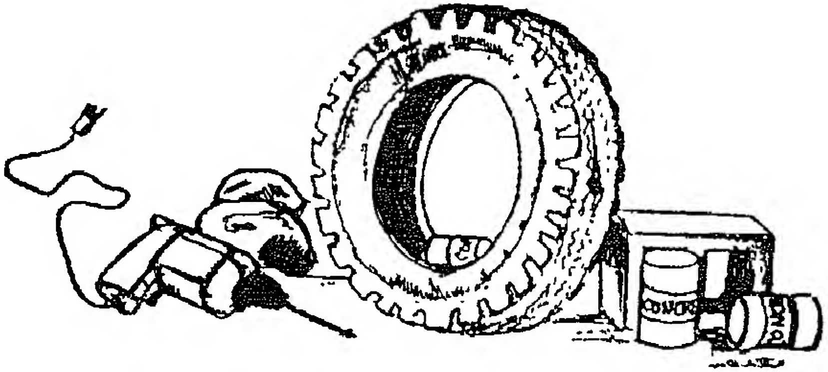
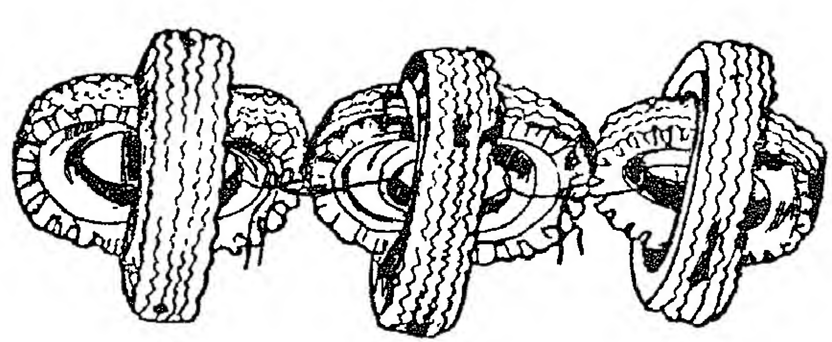


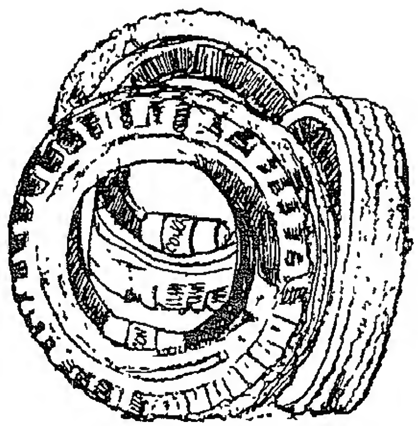
FIGURE 4 - FISH SHELTERS



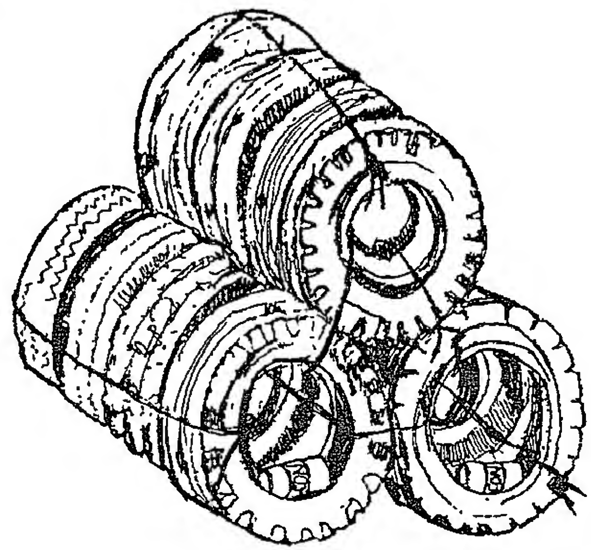
Single Tire Unit (with weights)



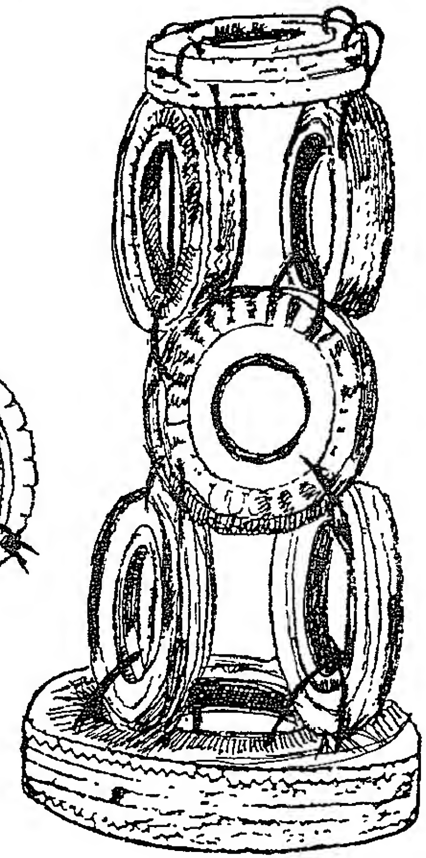
Tire Chain Unit



Triangle Tire Unit

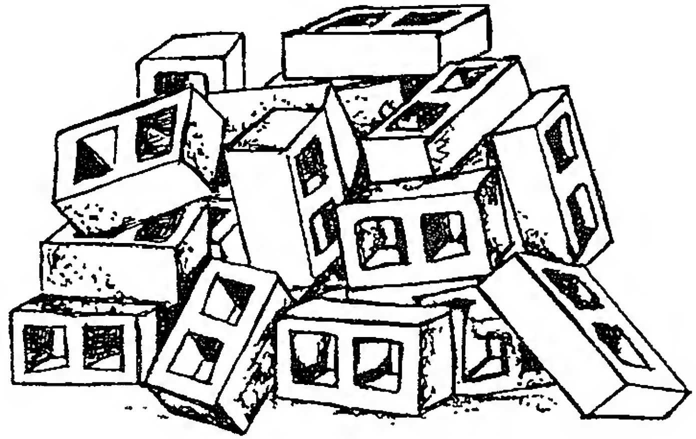


Pyramid Tire Unit

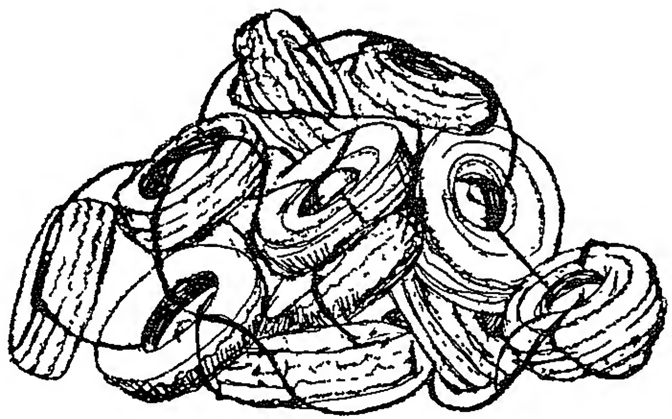


High Profile Tire Unit

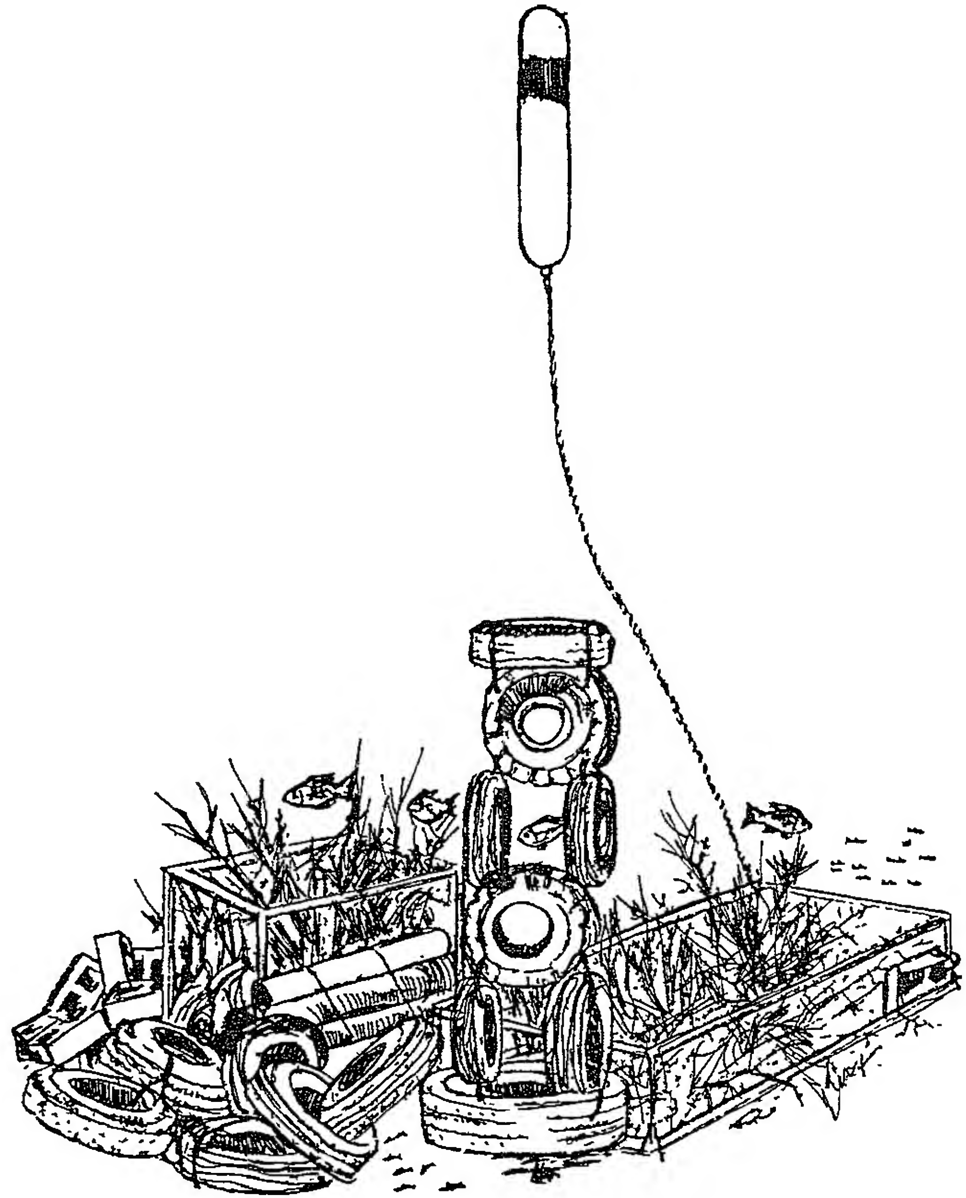
FIGURE 5 - FISH SHELTERS



Concrete Block Attractor



Random Pile Tire Structure



An Ideal Attractor

FIGURE 6 - FISH SHELTERS

Largemouth Bass

The largemouth bass is a member of the sunfish family which includes such species as bluegill, redear sunfish, and green sunfish. The true bass family includes species such as white bass, yellow bass, and the striped bass. The largemouth is usually dark green to lighter green on the sides and white on the belly.

The smallmouth bass and the spotted bass are often confused with the largemouth bass. The largemouth has a deep notch in the dorsal fin, an upper jaw which extends behind the eye, and a continuous lateral black band on its sides. The smallmouth has a shallow notch in the dorsal fin, an upper jaw which does not extend behind the eye, and no prominent lateral band on its side. The spotted bass has a shallow notch in the dorsal fin, an upper jaw which does not extend behind the eye, and lateral bands consisting of series of widened blotches.

The largemouth feeds on insects, fish, crayfish, tadpoles, frogs, snakes, and nearly any other animal small enough to consume. Young fish feed throughout the day, but adults often concentrate their feeding in late evening and early morning. The production of one pound of bass requires three to five pounds of natural food.

Although bass tend to gain more weight in the second and later years than in the first year, they grow more in length during the first year of life than in the second.

The world record largemouth weighed over 22 pounds. The Arkansas hook and line record is 13 lbs 2 ozs. The average adult largemouth caught by Arkansas pond fishermen weighs one to two pounds and is 12 to 15 inches long. Their life expectancy is about eight to ten years, but some live longer. Females tend to grow faster and live longer than males.

In Arkansas, largemouths usually spawn during their second spring when they are nine to twelve inches long. Spawning occurs when the water temperature is between 60 and 70°F. The male uses his tail to sweep a depression in the pond bottom, usually in water from 2 to 6 feet deep. Size of the nest depends on size of the male and may be two feet in diameter and six inches deep. The nest bottom may be mud, leaves, or roots. Upon finishing the nest, the male encourages a female into it and fertilizes the eggs as they are deposited. A single female deposits from 2,000 to 15,000 eggs depending on her size and condition. The male then guards the nest, aerates the eggs, and keeps sediment away from them by fanning with his tail.

The eggs are 0.1 inch in diameter and hatch in 3 to 12 days based on water temperatures. A yolk sac is attached to each bass fry and provides food for about one week. After the yolk sacs are absorbed, the young bass leave the nest in a school to search for microscopic animals. The male attempts to protect its offspring for about 10 days after they leave the nest. The fry remain in a school until they are about one inch long and then scatter into shallow water for protection.

Three major factors threaten bass reproduction and survival: (1) sudden drops in water temperatures when eggs or fry are in the nests; (2) predation on eggs and fry by other fish (especially other sunfishes); and (3) insuffcent food when the fry leave the nest.

Bluegill

The bluegill is a deep-bodied sunfish with a small mouth. Males are dark and gray to bluish on the sides with the belly being deep orange. Females are lighter colored and exhibit a light yellow, light gray, or cream-colored belly. Both sexes usually have a dark spot on the rear portion of the dorsal fin, faded vertical bars on the sides, and a dark blue or black "ear flap."

Bluegills feed on insect larvae, water fleas, adult insects, algae, freshwater shrimp, small crayfish, snails, fish eggs, small fish, including fry, and worms. They may feed on plants during mid-summer because of the scarcity of aquatic insects. One pound of bluegills can be produced from 4 to 6 pounds of natural food.

The largest bluegill on record was 4 lbs 12 ozs., while the Arkansas record is 2 lbs 1 oz. The average bluegill caught by Arkansas' anglers weights around 1/3 lb. and is 7 - 8 inches long. Bluegill growth is very restricted in many Arkansas ponds due to populations which are too large for available food and space.

Bluegills usually spawn at one year of age in Arkansas. The major spawning season begins in mid-May and continues through June.

Four to six years is the average life span of the bluegill in Arkansas, but records reveal this species reaching 13 years of age. Their life span under crowded, slow-growing conditions is only four to five years.

The number of eggs produced by the female depends on her size and condition and will vary from about 2,000 to nearly 50,000. There may be two or three spawnings each year from mid-April or May through September in water usually from 75 to 80^{o}F, but spawning may also occur in water temperatures in the high 60's.

Bluegills nest in colonies in water which is usually one to three feet deep. The male fans the pond bottom with his tail to form a depression about 12 to 16 inches in diameter in which the female lays the eggs. The male then fertilizes the eggs and guards the eggs and fry. The eggs hatch in two to five days depending on water temperatures. The fry remain in the nest for three to five days while the yolk sac is being absorbed before dispersing in shallow water.

The pond may quickly develop a bluegill overpopulation unless there are enough largemouth bass to effectively prey on these small bluegills.

Redear Sunfish

The redear sunfish is characterized by a bright red margin on the ear flap of the male and an orange-margined ear flap on the female. The redear has a slightly more elongated body shape than the bluegill.

The food habits of the redear are similar to those of the bluegill; however, the redear has a fondness for snails. Their pharyngeal (throat) teeth are broad and flat, making them well-suited to crushing the shells of mollusks. The redear actually cracks the shell, expels it, and swallows the remainder of the snail. This feeding habit has resulted in their being called "shellcrackers." Redears usually feed near the pond bottom and rarely feed near or on the surface.

The spawning habits of the redear resemble those of the bluegill. The redear spawns in water slightly deeper and at water temperatures (68^{o} to 75^{o} F.) slightly cooler than do bluegills. They usually spawn only once per year. The redear produces only 2,000 to 10,000 eggs per female. These eggs hatch 6 to 10 days after being fertilized by the male. Young fish remain in the nest for about one week after hatching. The male guards the nest from the time the eggs are deposited until the fry leave the nest.

Redear sunfish are successfully stocked in farm ponds in combination with bass and bluegill. The redear exhibits a growth rate very similar to that of bluegills; however, fewer redear than bluegills will be caught from the pond due to the higher reproductive rate of the bluegill.

The largest officially recorded redear caught in Arkansas so far weighed 2.5 lbs., but most redears in the fishermen's catch here will weigh about 4 to 9 ounches.

<u>Channel Catfish</u>

The channel catfish closely resembles the blue catfish. Its rounded anal fin (that fin on the lower body just forward of the tail) ha⁻ 24 to 30 rays, while the usually rectangular anal fin of the blue catfish has 30 to 36 rays. Both the channel and blue catfish, unlike bullheads, have deeply forked tails.

Channel catfish eat many types of living and dead matter, including seeds, insects, insect larvae, crayfish, worms, snails, clams, and fish. They feed by touch, taste and sight, having barbels near the mouth which respond to both touch and taste. Many of the foods of small catfish include insects and insect larvae. Larger channel catfish will eat small fish, but they do not significantly reduce large numbers of small bluegills in a pond.

The official Arkansas state sport fishing record for channel catfish is 18 pounds. The average fish caught by Arkansas anglers probably weighs from one to two pounds. In farm ponds, channel catfish grow at a rate of about one pound per year. Growth rate depends on stocking density and food availability.

Channel catfish reach sexual maturity when they are 13 to 16 inches in length. They usually do not spawn in farm ponds unless cavities such as hollow logs or muskrat dens are present, although they occasionally spawn in ponds without any cover. Milk cans and wooden boxes have been used to increase spawning success. Without such natural or artificial cover, channel catfish spawning in farm ponds is unpredictable.

Spawning begins when water temperatures reach 75^{o}F. Channel catfish usually spawn in Arkansas from mid-May through mid-July. The male builds the nest in a cavity and the female deposits about 2,000 eggs per pound of body weight, if she is in good condition. The eggs hatch in 6 to 10 days and the fry remain in the nest for about 7 - 10 days before dispersing. The male guards the nest from the time the eggs are laid until the young leave the nest.

Channel catfish have been successfully stocked alone and in combination with bass, bluegill, and redear sunfish in ponds. They can reproduce when stocked without other fishes and with suitable nesting

cover. However, they usually do not reproduce successfully in bass-bluegill ponds, since these species prey on both the eggs and fry of the catfish.

White Amur (Grass Carp)

The white amur is a native of Siberia, Manchuria, and China, inhabiting the rivers which flow into the Pacific Ocean. Before its introduction in the United States, this fish was successfully established throughout Southeast Asia, Europe, and Russia.

This fish was imported into Arkansas in 1963 from Malaysia by the U. S. Fish and Wildlife Service's Fish Farming Experiment Station near Stuttgart. Purpose of this importation was investigation of the fish as a biological control of unwanted vegetation.

The white amur has an elongated, moderately compressed body, greenish-brown on top, silver on sides and bottom. The mouth contains no teeth, but two rows of comb-like pharyngeal teeth are imbedded in each side of the throat. The movement of these teeth against each other and against a horny pad on the roof of the pharynx grinds vegetation into pieces which can be swallowed.

White amur grow rapidly and may reach a length of four feet and weigh up to 100 pounds. They begin to feed on aquatic vegetation when about one inch long, but young are reported also to feed extensively on mosquito larvae and aquatic insects.

Although they can tolerate oxygen levels as low as 0.5 ppm, white amur are more susceptible to rotenone than are common carp and are easily killed by this chemical. Tests have shown that white amur are killed with one-tenth the amount of rotenone required to kill all fish in a pond.

White amur, which reach sexual maturity at three years of age, will not naturally spawn in a pond. However, spawning can be induced by injecting them with a carp pituitary extract. Temperature and increased velocities of currents are two factors that seem to initiate their spawning in nature. Their reproductive requirements make it a very inefficient spawner, especially in short rivers or in areas where dams have reduced the current below the required level for proper incubation of the eggs. This fish spawns in strong currents (1 - 5 feet per second) after a fast rise in the water level. Their eggs must be kept off the stream bottom for several hours, and the fry also need the current to hold them off the bottom and in motion to escape sediments and predation. Upon hatching, the fry are very immature, much more so than the common carp, and are very susceptible to sediment and predation.

The white amur has proven itself as an effective control of many aquatic weeds. Although they seem to prefer filamentous algae and pond weeds, they also feed on a variety of other plants. These include duckweeds, milfoils, reeds, rushes, sedges, watercress, smartweeds; but <u>do not</u> include alligatorweed and bullrushes. White amur may or may not feed on floating leaved plants, such as water lilies and water hyacinth, so they should not be expected to control such plants. Larger amurs may push down and feed on cattails, but should not necessarily be expected to control them. Their use of algae has been reported to decline drastically once they weigh about five pounds.

White amur are not totally herbivorous. Adults do prefer plant foods, such as, grass, tree leaves, weeds and nearly all kinds of aquatic plants. But they also feed on insects, worms and even cow manure, banana leaves, old shoes and decaying clothes.

Fingerlings may be even more omnivorous than large fish. Young white amur have been known to consume large numbers of mosquito larvae.

The white amur eats large quantities of food per day, with estimates as high as two to three times its body weight. Its intestine is short in comparison to most herbivores (about 1/5 the usual length), thus about 50 percent of its food passes through undigested. This fecal material may provide desirable amounts of fertility in some ponds, while leading to over-fertilization and eutrophication in other ponds. However, this material also serves as food for organisms farther down the food chain and should not be considered as merely waste material.

Flesh of the white amur has an excellent flavor and texture. It is a far better food fish than the common carp. Its many small rib bones are objectionable in small fish, but are easy to handle in large fish.

They have potential as a game fish, having been caught on spinners, spoons, dry flies, streamer flies, dead and live minnows, liver, worms, algae and even grass. White amur are very wary and are strong swimmers, but will jump occasionally after being hooked.

UNDESIRABLE FISH IN FARM PONDS

Several undesirable species of fish are found in ponds in Arkansas. These fish find their way into ponds by intentional stocking, by swimming upstream through the pond spillway, or by swimming downstream into the pond. In order to prevent such fish in a pond, stock only those species recommended by those knowledgeable of pond fisheries, construct a spillway which will prevent fish from swimming upstream into the pond, and poison or otherwise remove fish from areas upstream of the pond before stocking.

The most commonly occurring undesirable fishes found in farm ponds are green sunfish, crappies, and bullheads. The following descriptions of the habits of these fish explain why they are undesirable in most farm ponds.

Green Sunfish

Also called "rice slick" and "perch" in Arkansas, the green sunfish is characterized by a large mouth extending beyond the front of the eye and a clear margin around the "ear flap." The body shape is not as deep as the bluegill and certain other sunfishes. The ventral fins of the green sunfish are bordered with white and yellow.

The green sunfish has feeding habits similar to the bluegill. The larger mouth allows it to consume larger food items than the bluegill. They not only compete with bluegills for food, but also consume young bluegills.

The green sunfish nests in colonies throughout the late spring and summer months. It spawns when one year old at a size of three inches. Females each produce 2,000 to 10,000 eggs. They compete with bluegills for spawning space and tend to spawn for a longer period of time than the bluegill. Especially in ponds where bass are overfished, green sunfish will soon overpopulate. Such overpopulation results in stunted green sunfish, bluegill, and redear.

Green sunfish help to control bullheads and channel catfish, preferring to feed on these catfishes to most other fish. They will swim under a school of smaller fish and dart up to them to eat one fish at a time.

Bullheads

Bullheads are members of the catfish family and are often referred to as "mud-cats." Arkansas has three species of bullheads: black, yellow, and brown. Bullheads usually have brown, black, or gray backs and sides and white or yellow bellies. Bullheads do not have the deeply forked tails of the blue and channel catfish.

Bullheads are undesirable in ponds because they have high reproductive rates and quickly overpopulate ponds if bass are not present. If bass are present, the bullhead population will decrease drastically in the pond. The effectiveness of bass in causing bullheads to disappear from ponds is because the young bullheads have a habit of swimming in schools for about one month after hatching. This makes the young fish very prone to predation by bass. As the larger bullheads are caught from the pond with no young ones to replace them, fishing for

bullheads will become very poor, and they will occasionally be totally eliminated from the pond.

Large populations of bullheads can cause the pond water to become muddy due to their bottom feeding characteristic.

Crappies

Crappies are members of the sunfish family. Both the black crappie and white crappie occur in most large rivers, larger reservoirs, and impoundments. These are their favorite habitats in Arkansas where they are considered a very desirable game fish by most fishermen. For this reason, many farm ponds have been stocked with them. Some success has been realized with black crappie in ponds over three acres in surface area. However, neither species is recommended for ponds under three acres in area.

They have not been successful in most ponds in Arkansas because of their spawning and feeding habits. Crappies spawn earlier in the spring than bass, and thus their young are too large to be eaten by the young bass throughout most of the summer. This results in very little predatory pressure on the young crappie needed to prevent it from becoming over crowded. Large bass and crappie prefer similar foods and consume smaller bass and crappie. Since crappies spawn in colonies and produce from a few thousand to 100,000 young per female per year, they quickly become much more abundant than bass which produce only 2,000 to 15,000 eggs and spawn in single uncolonized nests. As a result, crappies tend to quickly overpopulate, become stunted, and reduce bass populations in farm ponds.

Gizzard Shad and Golden Shiners

The gizzard shad and golden shiners, unfortunately, have populated some Arkansas ponds through stocking and other means. Deliberate stocking of these fishes have been made to supply food for bass, but they nearly always result in pond failures. These fishes do not compete for food to any extent with bass, bluegill, or redears, but the bass tend to concentrate their feeding on the shad and shiners instead of the bluegills. This leads to the inevitable overpopulation by bluegills.

ELIMINATING FISH PRIOR TO STOCKING

A well-planned fishery management program for a pond is dependent on a successful initial stocking of the right species and numbers of fishes. This can seldom be accomplished if wild fish are already in the pond or enter the pond after the desired stocking takes place. These extraneous fishes compete for space, oxygen, and food as well as increase the opportunities for parasites and diseases.

All fish should be eliminated from potholes, or any other water in the pond site or watershed areas when construction is complete or before the pond is filled. If some of the watershed is not owned by the pond owner and it includes a stream that supplies water to the pond of if the stream flows through marshy or swampy areas, this water should not be impounded until it is too cold for the wild fish to spawn. Wild fish will always be a potential problem in ponds that have watersheds with such streams. Therefore, alternative pond sites without such problems should be considered.

October is an ideal month to eliminate wild fish from a pond and its watershed, but it may also be done successfully from October to February. Fish spawning is generally over by October in Arkansas and, in case some fish do survive the elimination efforts, they will not be reproducing until the following spring by which time they may have succumbed due to natural causes.

Powdered or liquid formulations containing 5 percent rotenone or its equivalent should be used to eliminate fish in the pond and watershed area. The district fisheries biologist and local game warden with the Arkansas Game and Fish Commission should be contacted about the use of this chemical, especially if any streams are involved.

Rotenone is not harmful to livestock when used as directed. Powdered rotenone should be thoroughly mixed with water to obtain a "soupy" mixture. Liquid rotenone should also be diluted with enough water to facilitate effective treatment of the given area. Because the active ingredients in rotenone formulations vary, it is best to follow directions on the container to determine specific application rates.

If the formulation being used is five percent active rotenone, treat potholes with three pounds of liquid rotenone or six pounds of the powder per acre foot of water. Use six pounds of liquid or twelve pounds of powder of five percent rotenone for each 0.25 mile of stream that averages up to one foot deep and ten feet wide. A second treatment may be necessary to eliminate all fish.

STOCKING THE POND

Correct stocking of the pond is very important. The original stock of fish must provide the fishing for the first two to four years. It also determines the pond's future fishing potential and, to a large extent, how soon this potential may be reached.

Sport fishing will be produced faster by stocking the correct number of fingerlings than by stocking a smaller number of adult fish. When the right species and numbers of fingerlings are released, they will grow rapidly and produce fishing by the second summer.

Largemouth bass, bluegills, redear sunfish, and channel catfish are the fishes most highly recommended for stocking ponds in Arkansas. Pond owners should seriously consider their fishing plans and interests in managing the pond before deciding on what species to stock. Significant fishing pressure should be planned for bluegills and redears during the growing season. This means harvesting about 5 times as many pounds of bluegills and redears as bass. Not over 25 pounds of bass per acre of fertilized pond should be removed per year. However, if he or she is not interested in bluegills and redears and knows that significant fishing pressure would probably never be given them, then this pond owner should develop the pond with catfish as the main species.

Bass-bluegill ponds require proper regulation of the fishing to harvest enough bluegills to prevent their tendency toward overpopulation and stunting. However, channel catfish can be safely stocked in most ponds with little danger of overpopulation because special spawning facilities are usually necessary for their reproduction. A pond with only channel catfish can be restocked as needed to replace angling losses. Adequate fishing can thus be provided with less management by the pond owner.

Pond Fish and Fishing in Illinois by A. C. Lopinot lists the following conditions under which channel catfish will reproduce in ponds:

1. Stocking - Not more than 50 fish per surface acre should be stocked. Equal numbers of breeder size males and females should be stocked (13 to 16 inches long). A well-developed male usually has a large head, wider than the body, and the female has a slender head. Just before spawning time the vent of the male is small and opens toward the tail; the vent of the female is wide open and completely inflamed.

2. Acclimatization - Adult catfish caught in a river should be in the pond for at least one year before reproduction can be expected. Fish reared in ponds can be expected to spawn when mature, even if moved to a new or special spawning pond without acclimatization.

3. Suitable Nesting Place - Running water is not a requirement for channel catfish spawning. Catfish require some type of cavity in which to lay their eggs. A satisfactory nest consists of two nail kegs telescoped together to form a long tube with one end closed. The end of the double keg should be slightly higher than the closed end to prevent the fry from leaving prematurely after hatching. Sand or gravel can be placed in the bottom of the keg and the keg

should be staked to the bottom in water that is three to four feet deep. Lard cans, 10 gallon milk cans, truck tires, tile, etc., are also suitable nesting containers.

4. Survival of Young Fish - If the water is turbid (a white object disappears when less than 12 inches deep in water), the survival rate may be good. If the water is clear, the survival rate may be poor. Aquatic vegetation will not appreciably increase the survival rate. In the presence of large panfish populations there may be no survival of young channel catfish.

Channel catfish are recommended for stocking in ponds of any size. Where channel catfish only are to be stocked, the following rates should be used: 275 fish per acre in unfertilized ponds, 375 to 400 fish per acre in fertilized ponds, and 750 to 1,500 fish per acre if the fish are to be fed a commercial catfish food. One should remember before selecting a stocking rate that as the density of fish increases, the possibilities of oxygen depletion and disease problems increase. Therefore, if a pond owner is going to feed his fish a commercial fish food, but does not have facilities for aerating his water during periods of low oxygen, it would be much wiser for him to select a density of 750 fish per acre. In order to control other fish, such as green sunfish, which might enter the pond, approximately 10 bass per surface acre of water should be stocked. Stock the bass during the spring after stocking the catfish the preceding fall. Any bass caught should be placed back in the pond. Since the bass will control "wild fish" as well as any catfish reproduction, channel catfish will have to be restocked periodically as they are removed from the pond. When restocking, catfish measuring 8 inches or greater in length should be stocked since bass eat smaller ones.

If bass are not added to the catfish pond, then reproduction of the channel catfish may occur. However, this reproduction may be difficult to control and an overpopulation of catfish could result.

One pound of fathead minnows per acre could well be stocked in a pond with only channel catfish or channel catfish and bass. The minnows will provide food for the catfish and bass and will be a good supplement to the commercially prepared food for the catfish.

Fathead minnows are not recommended for ponds stocked with bass, bluegills, and redears. The minnows distract the bass somewhat from preying on the bluegills and redears and increase the possibility of an overpopulation of these bream.

The following species combinations are recommended only for stocking in ponds greater than one acre in size: bass-bluegill, bass-bluegill-channel catfish, bass-bluegill-redear, and bass-bluegill-redear-channel catfish. Table 1 displays the correct stocking rates for each species combination in unfertilized and fertilized ponds.

It is very important to use the stocking rates for fertilized ponds only, provided a fertilization program is begun soon after stocking and continued thereafter. If fertilization is begun and then discontinued, the quantity of food in the pond will be decreased resulting in too little food for too many fish. The fish will respond to this situation by becoming stunted. If there is any doubt about whether or not the pond will be fertilized, the stocking rate for an unfertilized pond should be used.

TABLE 1 - RECOMMENDED STOCKING RATES AND SPECIES COMBINATIONS

FOR FARM PONDS LARGER THAN ONE ACRE

Stocking Combination	Unfertilized Pond				Fertilized Pond			
	Bass #/Acre	Bluegill #/Acre	Redear #/Acre	Channel Catfish #/Acre	Bass #/Acre	Bluegill #/Acre	Redear #/Acre	Channel Catfish #/Acre
Bass-Bluegill	50	500	-	-	100	1,000	-	-
Bass-Bluegill-Channel Catfish	50	500	-	50	100	1,000	-	100
Bass-Bluegill-Redear	50	350	150	-	100	700	300	-
Bass-Bluegill-Redear-Channel Catfish	50	350	150	50	100	700	300	100

Channel catfish, bluegill, and redear should be stocked in the fall; largemouth bass should be stocked the following spring. If channel catfish are to be added to a pond already containing adult bass, the catfish should be at least 8 inches long to help prevent their becoming food for the bass.

White amur can be successfully stocked with any of the game fish combinations mentioned above to control algae, pondweeds, and other types of aquatic vegetation. Stocking rate is 8 to 12 per surface acre. These white amur should be at least 8 inches long if adult bass are present to prevent them from being eaten by the bass.

If the purpose for using white amur is mainly to control only algae, larger specimens (over five pounds) should be removed after several years and smaller ones restocked. The effectiveness of this species in controlling algae decreases after its size reaches about five pounds.

Many pond owners make the common mistake of over-estimating their pond area when applying for fish. It is important for them to measure their ponds accurately (to the nearest 0.1 acre) before filing an application for fish. Over-estimation results in too many fish with some large fish being produced, but usually becoming over-populated with small bluegills by the end of the first summer.

The random stocking of fish from other ponds and streams has been a major cause of pond failures throughout the country. Very rarely can the haphazard introduction of various fish species into a pond result in good fishing.

WHEN TO BEGIN FISHING

Fishing for channel catfish can begin the first July or August after stocking. At this time, the fish will average from 3/4 to 1 pound in size. An accurate record should be kept of the total number and weight of fish removed from the pond so it can be periodically restocked with channel catfish, as needed.

Fishing should not begin for largemouth bass, bluegill, or redear until June of the second summer after stocking. At this time, the fish should have spawned, the fish population should be approaching a balanced condition, with the total weight of fish composed of mostly harvestable-sized one-pound bass and 1/4-pound bluegill and redear.

A minnow seine should be used to check for fingerling bass (bass spawning success). If for any reason the bass have not spawned by June, fishing for bass should be delayed until the next year.

FEEDING CHANNEL CATFISH

A regular feeding program is the best way to attain high yields from channel catfish in ponds. Good catfish feeds contain 30 to 32 percent protein, at least 5 percent fat, 10 to 20 percent carbohydrates, and 10 to 15 percent fiber.

Commercially prepared catfish feeds are either meal, floating pellets, or sinking pellets. Meal is used primarily for feeding fry and is not usually fed in farm ponds stocked with fingerlings or larger fish.

Floating feed is one of the most useful management tools, especially for the inexperienced pond owner. Being able to observe the fish while they feed helps insure that the desired quantity of commercial ration is being used. If no feeding activity is seen, steps should be taken immediately to find the cause. However, a week or more may be required to train channel catfish to eat floating feeds.

Certain disease or water quality problems may be detected by observing the fish as they feed. Certain nutrients, especially carbohydrates, are more digestible in floating feeds than in sinking feeds. Good floating feeds also remain stable for hours in water.

However, floating feeds usually cost about 8 to 15 percent more than sinking feeds because of higher equipment costs and more energy required in their production. Fish may also fill their stomachs with floating feeds without consuming enough nutrients for maximum growth rate due to expansion of the food.

Use a 1/8-inch pellet for fingerlings and a 3/8-inch pellet for fish weighing 1/2 pound or more. Check pellets for hardness with each purchase. When dropped in water, 90 percent of the pellet should remain together after 10 minutes.

In general, the amount of food consumed by a catfish on a given day depends on fish size, water temperature, water quality, weather conditions, density and energy content of the feed, amount of food consumed the previous day, number of times fed per day, palatibility of the feed, and perhaps other factors.

When surface water of the pond is about 70^{o}F, feed enough pounds per day to equal 3 percent of the estimated total weight of catfish in the pond. This amount is fed 6 days per week. Such a feeding rate (in pounds per day) for 300 fingerlings which averaged 4 inches in length when stocked would be:

March	- 0.2	August	- 2.5
April	- 0.5	September	- 3.5
May	- 1.0	October	- 3.5
June	- 1.5	November	- 2.0
July	- 2.0		

Continuing with some feeding during winter will help prevent weight loss and the fish will be more resistant to diseases and parasites. Where water 6 inches below the surface is below 45^{o}F, feed 0.5 percent

of estimated total weight of fish in pond every 4 or 5 days. When water is between 45° and 60°F, feed 1 percent of the weight 6 days a week. Feed 2 percent when water temperature is between 60° and 70°F.

Scatter feed in 3 to 4 feet of water at the same time and place each day 6 days a week. Early in the morning or late in the afternoon are good times to feed.

Self-feeders are good for saving time and labor. Fish learn to obtain food by bumping the underwater release. These feeders are also helpful in winter since at this season it is difficult to know when the fish will feed. Place only a one-day supply of feed in the feeder to avoid overfeeding.

Some hand-scattering of food should be used with a self-feeder to help prevent a wide variation in fish sizes. But never feed more than 30 pounds per acre per day unless water is flowing through the pond. Excessive feeding usually results in an oxygen shortage.

If sinking pellets are used, check feeding with a 4- by 4-foot tray placed on the pond bottom in the feeding area before feeding. Lift the tray slowly an hour after feeding. If all the feed has not been eaten in one hour, reduce the amount of feed.

FEEDING BLUEGILLS

Stunted fish populations, such as those often created by bluegills, have been a continuous problem to pond owners. An upcoming section on RESTORING PONDS WITH UNBALANCED FISH POPULATIONS describes methods for dealing with stunted fish populations. One way to solve this problem is by supplemental feeding to increase growth.

Basically, the production of fish flesh is dependent on fertility of the water which determines the amount of microscopic organisms that furnish food for fish fry and fingerlings. These in turn are eaten by larger fish. Since basic nutrients are limited in amount, this then determines how many pounds of fish can be successfully sustained by any body of water. Regular feeding of commercial fish food simply adds to these basic nutrients and increases the number of pounds of fish which can be grown and maintained in the pond.

In the late 1960's and early 70's, Leo Pachner, publisher of Farm Pond Harvest in Illinois, developed a successful bluegill feeding system. Mr. Pachner proved that by placing feeders in the water and periodically filling them with fish food pellets, it is possible to grow and maintain a population of large bluegills and thus provide consistently good bluegill fishing.

There are certain disadvantages to feeding fish. Time and money is needed to purchase and dispense the feed. A regular feeding schedule must be maintained so that the fish will become accustomed to being fed and will therefore feed readily. However, supplemental feeding should be seriously considered by pond owners who are anxious to improve their bluegill fishing success in the shortest possible time.

Another advantage to feeding bluegills is that largemouth bass are also attracted to the feeding area. When fish feeders are in place, small and large bluegills begin residing around the feeders to consume the pellets. Some bass also move in to feed on the pellets, but what attracts the really big bass to the feeders are the bluegills themselves. Therefore, anglers can improve their chances of good catches of bass and bluegill by fishing around such regularly supplied feeders.

Since bluegills will not feed off of the pond bottom, feeders must keep the food suspended. Bluegills will consume food in tilted trays, possibly because they may not wish to nose down vertically to pick up food.

When eating commercial food, larger bluegills will feed on the surface, but tend not to feed in the lower depths. The smaller bluegills tend to shy away from surface feeding, but readily feed at lower depths.

Any of several different types of feeders can be used successfully for bluegills. The feeder developed and distributed by Farm Pond Harvest consists of a plastic ring about two feet in diameter for confining floating pellets. A plastic tray about two feet square is suspended under the ring one to two feet at a 25^{0} angle. The tray, attached to the ring by four strings, is used to hold sinking pellets. A stake driven into the pond bottom and attached by a cord to the feeder will keep it from drifting with the wind.

For those who wish to construct their own feeders and save some money, they may wish to duplicate the Farm Pond Harvest feeder or build a platform feeder anchored by stakes in the pond bottom. This platform should contain a plywood tray about two feet square and two inches deep, secured to the four posts at a 25° angle. The tray should be 1-1/2 to 2 feet deep. If floating feeds are to be used with the sinking feed on the platform, a floating, plastic ring should also be attached by strings to the platform.

In pond feeding, 2 feeders per surface acre of water should be used. Place each feeder in water 3 to 5 feet deep to begin with and move them around, if necessary, until it is determined where the fish feed best. If good bass fishing is also an objective for the feeders, deeper water may be needed, but not always.

Commercial fish food should be used extensively for feeding because it is high in protein. Choose brands whose formulations contain at least 30 percent protein.

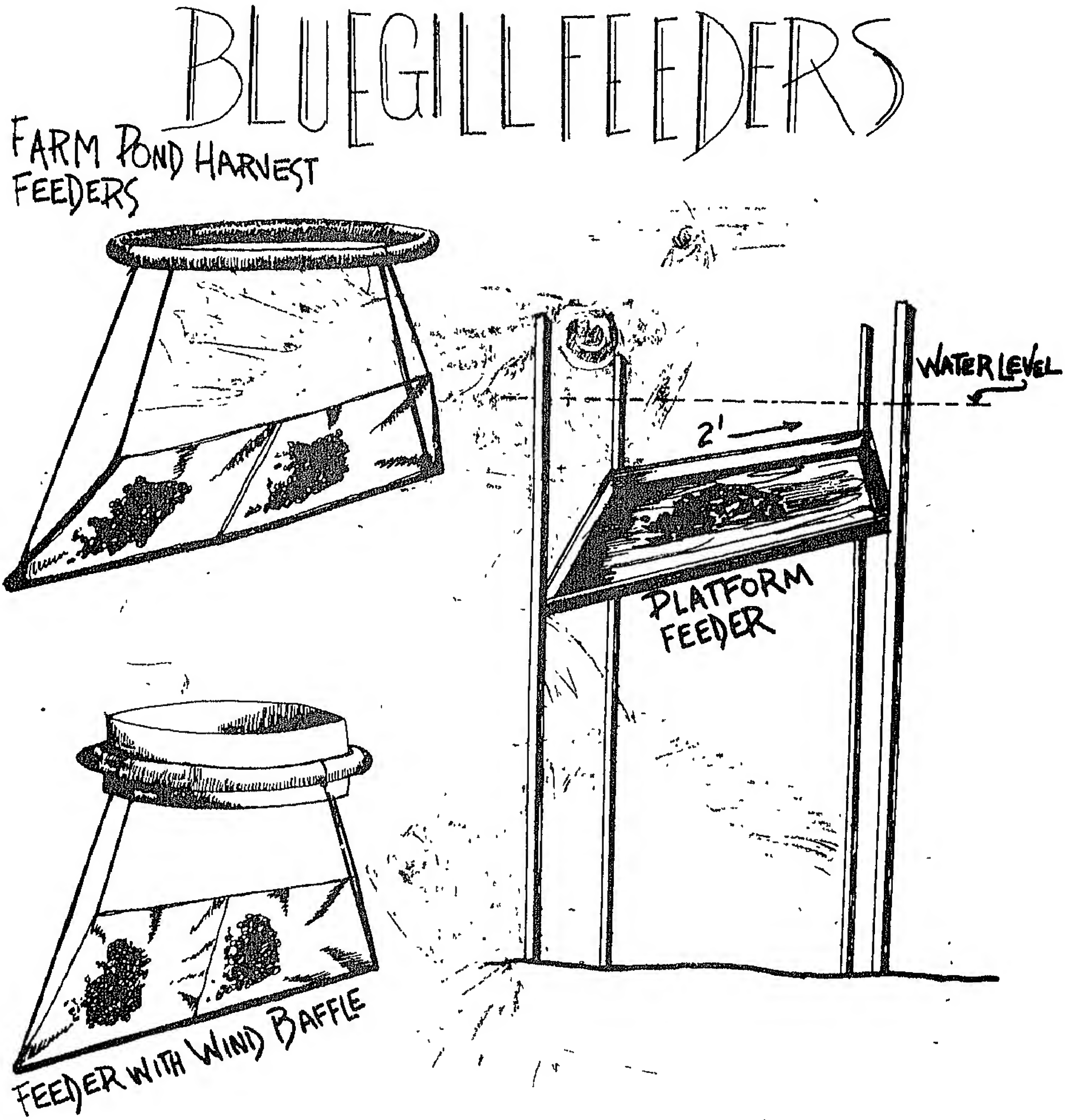
Pelleted feed should be used. There are various sizes and types of rations sold, but only the 1/8 inch pellet and 1/4 inch pellet should be used for bluegills. The 1/8 inch size should be in both floating pellets and sinking pellets. This size is good when most of the population is small or when small fish are mixed with larger ones. The 1/4 inch size should be the floating type for larger fish only and can be fed to fish longer than four inches.

In general, water temperatures between 65 and 90°F are the best for feeding, but the pond owner may begin when the water reaches 55°F. It will be important to maintain regular feeding hours during the first few weeks to get the fish used to feeding.

Bluegills may spit out pellets that are too hard until the water softens them. This can be prevented by soaking the pellets for a few minutes before they are placed in the feeders. In some cases, the fish may be reluctant to feed. If so, bread crumbs can be used to "chum" them in, then follow with pellets. Food quantity can be adjusted as the fish grow and more move into feed. But above all, the quantity of food used may well depend on how much time and money the pond owner can afford.

Some fishermen prefer to use a 20-foot pole with a can attached to one end to put pellets into the feeders. This helps prevent spooking the fish, especially bass, while filling the feeder.

FIGURE 7


BLUEGILL FEEDERS
FARM POND HARVEST FEEDERS
WATER LEVEL
2'
PLATFORM FEEDER
FEEDER WITH WIND BAFFLE

CONTROLLING FISHING PRESSURE

In order for a pond to provide good fishing, the rate at which fish are removed from the pond should be regulated. The following descriptions of carrying capacity and balanced fish population will help explain how a fish population can be manipulated by proper fishing.

Carrying Capacity

This term refers to the maximum weight of fish which a given pond can support. Many factors such as quantity of fish food and quality of water influence the carrying capacity of a pond. Fertilization can increase the carrying capacity of a pond by a factor of 3 to 5. The average carrying capacity is 100 to 150 pounds of fish per acre for unfertilized ponds and 400 to 600 pounds of fish per acre for fertilized ponds. The population of fish in a pond may consist of many small-sized fish, a moderate number of medium-sized fish, or a relatively small number of large fish; however, the total weight of these fish will not vary. For example, a one acre unfertilized pond with a carrying capacity of 100 pounds of fish could have 100 fish weighing one pound each, 200 fish weighing 1/2 pound each, or 1,000 fish weighing 1/10 pound each.

Balanced Fish Population

This term is often used when referring to the well-being of a fish population in a pond. A balanced fish population is one which consists of four to five pounds of bluegills or bluegills and redears for every pound of bass. In addition, 60 to 85 percent of the total weight of fish in the pond should be of a harvestable size.

Fish populations in ponds stocked with bass-bluegill or bass-bluegill-redear combinations first attain "balance" about the second June after initial stocking. At this time the total weight of fish in a pond is about equal to the carrying capacity. When fishing first begins, the larger fish which were initially stocked are those which are caught from the pond. As these larger fish are removed, the total weight of fish in the pond becomes less than carrying capacity. The smaller fish grow and replace the weight lost by removing the larger fish. This cycle continues and allows one to continue catching harvestable-sized bluegills, redear, and bass, provided that fish are removed at the proper rate.

The two most common causes of bass, bluegill, and redear populations becoming unbalanced are: (1) the lack of adequate fishing pressure on bluegills and redears, and (2) removing too many bass in too short a period of time, thus overfishing the bass population. If a pond is not fished enough, there will be many small fish in it. The total weight of larger fish removed from the pond by fishing will be replaced, but this weight will be distributed among many smaller fish. Therefore, no harvestable-sized fish replace those which have been removed. If too many fish are removed in too short a period of time, the harvested population may be replaced by excessive numbers of small fish, especially in ponds which are being fished for the first time after stocking. If too many bass are removed from a pond, then an overpopulation of stunted

bluegills will soon result since there are not enough bass to eat the bluegills which produce numerous offspring each summer.

Aquatic vegetation may add to the problem of overpopulation of bluegills and redears. When this vegetation becomes dense enough to conceal numerous small sunfish, the bass will not be able to catch as many of them. This may allow the bluegill and redear populations to grow in numbers beyond what their available food can allow for growth in size.

Harvesting

To maintain a balanced population, fish should be removed from the pond at the same rate as they are produced. Table 2 displays recommended harvest rates for fish ponds in Arkansas. If yearly harvest rates similar to these are followed, then good fishing can be maintained. One should develop a fishing schedule for his pond that does not result in removing all the recommended yearly harvest in a short period of time. Removal of the recommended yearly harvest over a 5-month period during the summer should not cause problems in maintaining pond balance.

By using the harvest rate in Table 2, the average bluegill caught will weigh 1/4 pound and the average bass will weigh 1 to 2 pounds. If one wishes to catch larger bluegill or redear, then the harvest rate for bass can be halved. This will cause more bass of smaller size to be present in the pond. These bass will reduce the numbers of bluegill and redear; however, the average size of the fewer bluegills and redear harvested by anglers will increase.

If the fishermen wish to catch larger bass, then 5 to 10 more pounds of bass per acre can be caught from the pond; however, the average size of bluegill and redear will decrease. Eventually this removal of excessive numbers of bass will cause the bluegill and redear populations to become overabundant and stunted. In fact, bluegill and redear can reach such a density that they will eat all bass eggs that are produced, and there will be no young bass to replace those which are caught by fishing.

TABLE 2 - RECOMMENDED HARVEST RATES FOR FISH PONDS STOCKED WITH BASS AND BLUEGILL OR BASS, BLUEGILL, AND REDEAR

Species of Fish	Largemouth Bass			Bluegill/and/or Redear		
Fertility	Low	Med	High	Low	Med	High
Carrying Capacity (Pounds Per Acre)	25	50	100	75	200	400
Harvest 1st Year (lbs)	None	None	None	38	100	200
Harvest 2nd Year (lbs)	None	None	None	38	100	200
Harvest 3rd Year (lbs) and each succeeding year	10*	20*	30*	38	100	200

*To further help maintain a good fish population, the fisherman should return bass less than 11 inches long to the pond.

ANALYSES OF FISH POPULATIONS IN PONDS

There are many farm ponds in Arkansas which presently provide poor quality fishing. One of the major causes for such poor fishing is unbalanced fish populations. Before correcting such a problem, one must analyze the fish population to determine the cause for the unbalanced condition. Analyses of fishing records and seining results can both be used to evaluate whether or not fish populations in ponds are in balance.

Fishing Records

One of the best indications of fish population balance in farm ponds is the quality of fishing. If fishermen consistently catch bass of 12 to 15 inches and bluegill or redear of 6 to 7 inches, the pond is in balance. However, if only a few larger bass, many small bluegill and redear or many small undesirable fish such as green sunfish, bullheads, and crappies are caught, the fish population is probably unbalanced. Table 3 illustrates how the fisherman's catch can be used to determine the status of a pond's fish population.

Seining

At Auburn University, Dr. H.S. Swingle developed methods whereby the status of fish populations could be determined by the use of seines. One of these methods involves use of a 12-foot seine and another method uses a 50-foot seine. In using either of the methods, a minimum of 3 seine hauls should be made before conclusions are reached about the overall status of the fish populations.

A 12-foot minnow seine (or a seine from 10 to 15 feet long) with a mesh of 1/4-inch may be used to seine fish around the shallow edges of a pond. This method should be used only during the months of June and July when both recently hatched bass, bluegill, and redear should be present in the pond. Table 4 shows the relationship between the presence of recently hatched fish in the seine and the overall balance of the pond. When using this method, totally ignore the presence of any larger fish in the seine and only base conclusions on the presence or absence of recently hatched fish.

Many times the use of a 12-foot seine will indicate that there is a problem with the fish populations, but does not yield enough information about larger-sized fish or undesirable fish in a pond. Use of the 50-foot seine will usually yield more information about various numbers and sizes of bluegills and redears as well as provide data about the presence of undesirable fish.

The 50-foot seining method involves sampling several shallow areas free of snags around the pond. A 1/4 to 1/2-inch mesh seine measuring 50 feet by 6 feet is used to seine during June, July, or August. This method should result in collecting various sized bluegills and redears, recently hatched bass, and smaller individuals of undesirable fish species. Bass greater than 6 or 7 inches usually are not caught in a 50-foot seine. Table 4 illustrates how to determine the status of pond fish populations by observing the fish collected with a 50-foot seine.

TABLE 3 - STATUS OF FISH POPULATIONS

BASED ON FISHERMAN'S CATCH 1/

	Fisherman's Catch	Status of Fish Populations
1.	Bluegills average 6 to 7 inches in length. Bass average 1 to 2 pounds (12 to 15 inches in length).	Balanced.
2.	Many small bluegills less than 5 inches in length. Only a few bass are caught and most of these are larger than 2 pounds.	Bluegills overcrowded and causing poor survival rate for young bass.
3.	Few bluegills caught but those which are caught average greater than 0.4 pounds (7-1/2 inches or greater in length). Bass average less than one pound.	Bass are overcrowded and causing a poor survival rate for young bluegill.
4.	Excessive numbers of undesirable fish such as small crappie, green sunfish, bullheads, carp, or goldfish.	Species of fish present which are not compatible with bass, bluegill, and redear populations in farm ponds.

1/ Revised from Pond Fish and Fishing in Illinois, by A.C. Lopinot, Fishery Bulletin #5, Illinois Department of Conservation, 1967.

TABLE 4 - STATUS OF FISH POPULATIONS BASED ON FISH COLLECTED WITH SEINES

12-FOOT SEINE

	Contents of Seine	Status of Fish Populations
1.	Young bass present, many recently hatched bluegills.	Population balanced.
2.	No young bass present, many recently hatched bluegills.	Bass or bluegills crowded.
3.	Young bass present, no recently hatched bluegills	Bluegills absent or undesirable species competing with bluegill.
4.	No young bass present, no recently hatched bluegills.	Overpopulation of bluegills or undesirable fish species overpopulated

50-FOOT SEINE

1.	Young bass and recently hatched bluegill present. Per seine haul, an average of less than 20 bluegills in the 4 to 5-inch size class.	Population balanced.
2.	Young bass present or absent, No, few, or many recently hatched bluegills. Per seine haul, an average of more than 20 bluegills in the 4 to 5-inch size class.	Overpopulation of bluegills.
3.	Young bass present or absent. No bluegills of any size.	Shortage of bluegills.
4.	No young bass. Many recently hatched bluegills. Per seine haul, an average of less than 20 bluegills in the 4 to 5-inch size class.	Bass may be overcrowded or young bass may have grown to a size where they can avoid the seine. If bass are overcrowded, fishermen should be able to catch small bass of 1/4 to 1/2 pound.
5.	No young bass, few recently hatched bluegills and very few 4 to 5-inch bluegills. Other species such as bullhead, green sunfish, or crappie present in seine.	Overcrowding by undesirable species.

General Seining Considerations

Individual pond conditions will help determine what seine size and method will work best. Obviously, the longer the seine, the more chance there is of snagging or encountering water too deep to sample. A seine 4 to 6 feet in depth should be used for any length of seine to allow for deeper water.

In general, the shorter the seine, the faster it should be pulled, but any seine should usually be pulled as quickly as possible once in position to help prevent fish from escaping.

Care should be taken to keep the seine reasonably taut and to keep the lead line in contact with the bottom throughout each haul. When the workers have each end of the seine at the bank, they should quickly place the poles on the ground and begin sliding the lead line in, being careful to keep it on the bottom until the fish are concentrated in the last few feet of netting.

RESTORING PONDS WITH UNBALANCED FISH POPULATIONS

Several measures can be used to correct unbalanced fish populations. The exact corrective measure that should be used will depend on which fish species is overpopulated and the extent to which overpopulation occurs.

Managing Bass Populations

Overpopulations of bass can best be controlled by sport fishing. If too many bass are present in a pond, increase the bass harvest rate in Table 2 by 3 to 5 pounds per acre per year for unfertilized ponds and 10 to 15 pounds per acre per year for fertilized ponds. Continue this excessive removal rate for two years or until the average size of bass caught approaches 1 to 2 pounds. If this average size has not increased after these two years, remove even more bass per acre per year until their average size increases to 1 to 2 pounds. Then revert back to the bass removal rates in Table 2.

If excessive fishing pressure (greater than that recommended in Table 2) is exerted on an average or even a good bass population, the pond may quickly overpopulate with bluegill or other species upon which the bass feed. In such cases, bass fishing should cease until the overpopulation of bluegill is corrected.

Managing Bluegill-Redear Populations

In ponds with bass but no bluegills, redears nor undesirable species, stocking of 100 to 200 adult bluegills and redears will usually result in desirable bluegill-redear populations. These fish should be at least eight inches long when stocked to prevent bass from eating them. Wait until after bluegills and redears have spawned before fishing for these two species.

Overcrowding of bass in a pond will result in very few bluegills surviving. However, the bluegills which do survive will attain a size of 1/2 to 3/4 pound in size. If bass are not wanted, but some large bluegills are, then this condition can be maintained by not fishing for bass. If there is interest in catching bass as well as more bluegills, the pond owner should remove excessive bass as explained in the section on managing bass. However, the average size of bluegills will decrease from about 1/2 to 1/4 pound.

Bluegills and redears will soon become overpopulated if not enough bass are present in the pond. When this situation occurs, one or a combination of the following alternatives will help remove excessive numbers of bluegills and redears.

Seining - Use a 1/2 to 3/4 inch mesh seine measuring 50 or more feet long and 6 to 8 feet deep to seine around the edges of the pond. Remove all bluegill and redear sunfish of 3 to 5 inches in size and return smaller and larger fish to the pond. Continue this process until seining only produces less than 5 to 10 fish of the 3 to 5 inch size class per seine haul. If the pond is to be fertilized, begin a proper fertilization program immediately.

"Draw-down" - If the pond is constructed so that the water level can be lowered, begin lowering it immediately following the bass spawning season. Keep the water level lowered to about 1/4 to 1/2 its

normal level throughout the summer and fall. Allow the pond to refill with water well before the bass spawning season. Repeat this process until a desirable bluegill population is obtained. "Draw-down" allows bass to reproduce over a wide area but reduces the area available for bluegill spawning. In addition, fish are more crowded and bass can prey on young bluegills more efficiently.

Trapping - If trapping is continued on a regular basis, it may prove beneficial in reducing excessive numbers of bluegills. Use a funnel trap constructed of 1/2 to 3/4-inch mesh hardware cloth or chicken wire. Traps should be baited with cottage cheese or cottonseed cake suspended from an open mesh bag and placed at a density of 3 to 6 traps per acre. Traps should be moved around in the pond until the most productive areas are located. Trapping in water less than 4 feet deep will normally produce good results in removing smaller bluegill. Remove all bluegills and redears from the pond that are less than five inches in length. Continue trapping bluegill and redear until less than one-third of the fish being caught are 3 to 5 inches long.

Increase Numbers of Bass - In ponds with an overcrowded bluegill population, a shortage of bass may be the cause of the problem. If fishing records indicate that only a few larger bass averaging more than 1 to 2 pounds are present in the pond, then stop fishing for bass. Stock bass weighing 1/2 to 1 pound each at a rate of 10 to 15 bass per acre in unfertilized ponds and 20 to 30 bass per acre in fertilized ponds. Use traps or seines to remove excessive numbers of 3 to 5 inch bluegills and redear. Resume fishing for bass at rates indicated in Table 2 only after excessive numbers of 3 to 5 inch bluegills have been removed.

Partial Fish Kill - If a pond is larger than 2 acres, a portion of the fish population can be killed with rotenone. But this can be difficult to do correctly; therefore, a biologist experienced in the use of rotenone should supervise such an operation. Even when following all precautions, a partial fish kill is a risk and the possibility of eliminating too many fish still exists.

The Arkansas Game and Fish Commission should be notified of any plans to use rotenone.

Total Fish Kill - Bluegills or undesirable species can become so overpopulated in a pond that the entire fish population has to be removed and the pond restocked with young fish at the proper stocking rates. In some ponds, the water can be drained and the fish removed. If draining is not practical, rotenone can be used to kill the fish. For best results, lower the water level as much as possible. This assures a more complete kill and costs less, since less rotenone is used. Flexible plastic pipes (2 - 4 inches in diameter) can be used as siphons to remove water, if the pond has no water control structure.

Rotenone is used as a fish toxicant because it is not harmful to most other aquatic animals. Rotenone kills fish by interfering with their ability to use oxygen. In effect, rotenone actually suffocates the fish. In order to obtain a complete fish kill, rotenone should be applied at a rate of 5.5 pounds per acre-foot of water. Rotenone should only be used when water temperatures are above 70°F since it is not as effective in killing fish at lower water temperatures.

Fish will begin to react to the rotenone approximately 30 minutes after it is applied to the pond. They will come to the surface and swim rapidly. Some of the fish will sink to the bottom of the pond and die. Within one or two days, these fish will begin decomposing and will float to the surface. If the correct dosage of rotenone is used in waters with temperatures above 70°F and proper mixing takes place, all fish should be dead within 12 hours. However, proper mixing is very difficult if the pond is completely full of water which can make an incomplete kill quite possible. Remember that the water level should be lowered as much as possible when using rotenone.

Normally, rotenone loses its toxicity on fish within one or two weeks after being applied to a pond with water temperatures greater than 70°F. Before restocking fish into a pond which has been treated with rotenone, be sure that the pond water is no longer toxic to fish. One way to do this is to place a wire basket or cage containing several minnows into the pond. If these minnows are still alive after one or two days, then the pond is safe for restocking.

If pond water which has been treated with rotenone is allowed to drain out of a pond, it may cause a fish kill in other ponds or in a stream. Therefore, pond owners should be very careful and notify the Arkansas Game and Fish Commission before using rotenone.

POND WATER - BASIC CHARACTERISTICS AFFECTING FISH

There are five properties of water which have profound ecological influences on creating and changing habitats for aquatic organisms.

Universal Solvent

Water will dissolve more substances than will any other liquid, hence it is called the universal solvent. Oxygen, carbon dioxide, and nitrogen are absorbed from the atmosphere. Oxygen is also contributed as a by-product of photosynthesis and carbon dioxide is released by both plants and animals in respiration and decomposition. Phosphates, chlorides, and similar mineral salts are dissolved in run-off and seepage water.

Surface Film

Water molecules are strongly attracted to one another through their two hydrogen ions. At the surface, this attraction produces a tight film over the water. A number of organisms live both on the upper and the lower sides of this surface film.

Water Density

Pond water experiences an annual cycle of seasonal temperature changes. The density of water is greatest at 39.2°F (4°C). Such water is found at the bottom of a pond when the pond's surface is covered with ice. The colder water above the bottom is less dense and the lightest water (about 32°F) is just under the ice.

During this <u>winter stagnation</u> period, the upper portion of the pond contains enough oxygen for aquatic life, but there may be little oxygen in the deeper parts due to consumption by bacteria decomposing dead plants and animals. At this time, there may not be enough dissolved oxygen in the deeper water to support fish and other aquatic life. Some oxygen may be produced by microscopic plants (algae) in the upper region of the pond just under the ice where enough light is available for photosynthesis. However, snow covering the ice can reduce light intensity to the point where oxygen cannot be produced.

As the weather becomes warmer, the pond's surface warms from 32°F to its maximum density at 39.2°F, and the heavy surface water sinks.

The surface water mixes with deeper water and the lighter, colder water rises from the depths, becoming oxygenated by spring winds. This <u>spring turnover</u> mixes the pond water so that water temperature is almost uniform at all depths and the entire pond has much oxygen. During mild winters in Arkansas, such winter stratification will not occur often.

A pond turnover may also be caused by a cool rain shower with wind and wave action forcing the surface layer to one side of the pond. When this happens, the cooler surface water falls to the bottom and forces the undesirable water to the upper portion of the pond. Upon mixing of the two layers, dissolved oxygen may be so low throughout the pond that a fish kill results. Also, gases (such as hydrogen sulfide, methane, and carbon dioxide) from the decomposition of organic matter by bacteria can also kill fish and are particularly toxic in low dissolved oxygen levels.

During summer, temperatures of the surface waters increase rapidly and become much less dense than the deeper, cooler water. This warm surface water stays at the top of the pond throughout the summer (due to its lightness) and does not mix with the cooler water below. In deep ponds, fish are mainly confined to the warm, upper levels of the pond during this summer stagnation period since the colder depths usually contain inadequate oxygen supplies.

In autumn, the surface water cools toward the temperature of the deeper water. As this water cools and becomes heavier, it sinks and mixes with the deeper water, until all the water has the same temperature and density. This is the fall turnover and its effect on fishes depends on the relative size of the well oxygenated top layer. As vertical circulation takes place, stagnant water moves to the surface. Here it releases CO_2 and other undesirable gases and is recharged with dissolved oxygen. A fish kill can result when this occurs, especially if it occurs rapidly when the surface layer is low in dissolved oxygen.

Heat Holding Capacity

Water has a very large heat holding capacity. It absorbs and releases heat much slower than does air. For this reason, plants and animals of most ponds and lakes are not usually subjected to sudden changes in temperature. Though the air temperatures may change rapidly and greatly, the water temperature of a deep lake changes slowly. In a shallow pond or lake, fluctuations in water temperatures are more closely related to changes in air temperatures.

Light Penetration

The transparency of water permits enough light to penetrate for plants to carry on photosynthesis. The depth to which light can penetrate decreases as water becomes more turbid. Few plants grow in muddy ponds because the suspended particles absorb light.

Light penetration leading to photosynthesis is responsible for shallow water areas producing more food than deep water. The sunlight and more available dissolved oxygen in shallow water result in increased rates of photosynthesis, greater amounts of plant growth, and thus more pounds of fish than deep environments.

WATER QUALITY

Good water quality is absolutely essential for successful fish production and fishing in ponds. Basic understandings of some major chemical and physical characteristics of pond water and how to improve them for fish production are very useful in assisting pond owners.

Temperature

Warm-water fishes grow best when water temperatures are above 64°F and below 90°F. Growth of the fishes slows when water temperatures are above 90°F, which causes the fish to go into a stressed condition. The growing season for these fishes can be extended by taking overflow water from the bottom to avoid the constant loss of warmer surface water in the spring.

Temperature differences cause ponds to have definite layers of water. The top layer where photosynthesis and most fish production takes place is called the epilimnion; it usually extends 3 to 4 feet deep and has a small but variable temperature gradient. Below this layer is the metalimnion, a zone distinguished by very steep and rapid decline in temperatures which may extend to about 15 feet. The thermocline, within the metalimnion, is the region in which the temperature drops most rapidly (1°C for each meter of depth). Deep ponds and lakes may have a third layer, the hypolimnion, a deep, cold region without large differences in temperature.

Oxygen differences also occur in these layers. As summer progresses, the epilimnion becomes smaller and the metalimnion gets larger, thus reducing the water of best quality. A "pond turnover" may happen anytime, but generally takes place in late summer or fall, during declining water temperatures, as described in the preceding section. However, turnovers can be caused by severe thunder showers with cool or cold rain or very strong winds.

Dissolved Oxygen

Dissolved oxygen (DO) is being used continuously by all pond life and is used by bacteria for the breakdown of organic matter (dead plants, feces, uneaten food). Certain chemicals in the water also react with DO to reduce its concentration in the pond. Dissolved oxygen is added to the water from the atmosphere at the exposed surface by wave action and by microscopic plants through photosynthesis.

The amount of DO in the pond will vary throughout the year and throughout the day. Water has a greater capacity to hold DO at lower temperatures. Therefore, DO concentrations in water are generally greater in winter than in summer. Since plants release oxygen only in the presence of sunlight during photosynthesis, the DO content of water will be greater during the day than at night. DO will reach its lowest level in a pond at sunrise, since no oxygen has been released by plants during the night, but oxygen has been used continuously throughout the night by plants and animals, including bacteria as they break down organic matter. DO concentrations in ponds commonly vary from 10 ppm during mid-afternoon to 4 ppm or less at sunrise.

At times, all of the dissolved oxygen in pond water will be depleted. Oxygen depletion normally occurs during a series of still, hot, cloudy, summer days and is most prevalent in ponds with dense growths of algae or other plants. Such conditions cause an oxygen depletion because;

1. Water does not have as much capacity to hold oxygen at the higher temperatures of summer.

2. Clouds reduce the intensity of light reaching plants in the pond and less oxygen is released by the plants through photosynthesis.

3. Due to reduced light intensity, a larger than normal portion of the plants die and oxygen is used by bacteria in decomposition of these dead plants.

4. There is no wave action on still days, thus no mechanical mixing of air and water takes place.

Oxygen shortages may also be caused by cold summer or fall rains with high winds which cause turnovers, as discussed earlier, by mixing deep water that is low in oxygen with surface water. The bottom water may also have other chemicals such as dissolved carbon dioxide, hydrogen sulfide, and ammonia in concentrations large enough to be toxic to fishes.

Pond owners who are interested in preventing a fish kill due to oxygen depletion should buy an oxygen test kit. Such a kit can be purchased for less than $30.00. Combination test kits ($70 - $80) are also available containing simplified equipment, procedures, and agents for testing DO, CO_2, pH, hardness, and alkalinity. Such a kit is especially designed for general pond management and would be quite useful to the serious pond manager.

Dissolved oxygen content should be checked at sunrise. If it is less than 2 ppm or if fish are swimming at the water's surface and "gulping air," immediate measures should be taken.

Correcting Oxygen Deficiences

Any feeding should be stopped immediately during periods of dissolved oxygen deficiences.

Fresh water should be added to the pond if at all possible. It is very desirable to have much freeboard for pond levees or banks so that water may be pumped into the pond faster than the drain will let it out. All water added to a pond should be sprayed into the air, splashed, or otherwise aerated as it reaches the pond. If a source of freshwater is readily available, remove 1-1/2 to 2 feet of water from the bottom, if possible, and refill. This may flush the toxic substance(s) out of the pond.

If it is not possible to add freshwater quickly to the pond, then an outboard motor may be used. This can be a good way to add oxygen, especially to ponds of less than one acre. But it may prove harmful, if too much of the bottom water is very poor (low DO, high CO_2, presence of much hydrogen sulfide, nitrogen, methane, urea, etc.). Mixing such water throughout the pond could do more harm than good, even though the outboard's use would lead to more dissolved oxygen. Check the water that is being removed from the pond bottom. If it has a very bad odor, do not use the outboard motor.

Another way of recirculating the water and adding oxygen is to pump it from the two top feet of the pond, spray or squirt it into the air, and have it fall on a platform or overturned boat to splatter as it reenters the pond.

Chances of a fish die-off can be reduced by designing the drainpipe so it removes water from near the pond bottom. Periodic removal of bottom water decreases the opportunity for toxic substances to accumulate to dangerous levels in the deep water.

Carbon Dioxide

The amount of free carbon dioxide in water is one of the best indicators of environmental suitability for fishes. This importance is derived mainly from three factors:

1. It "buffers" the environment against rapid changes in acidity and alkalinity, since it can combine with water to form an acid as well as react to give a neutral salt or a base.

2. Carbon dioxide concentration regulates certain biological processes (seed germination of some plants, plant growth, respiration and oxygen transport in the blood of aquatic animals. Carbon dioxide and water supply the carbon, hydrogen, and oxygen which are major components of protoplasm.)

3. It contains carbon, one of the most versatile of all elements due to its great bonding capacity which allows it to form a vast number of compounds. Carbon is distinguished from other elements and from inorganic substances by the asymmetrical nature of its bonds and by its ability to form chains of atoms almost without limit.

The very high solubility of carbon dioxide in natural water is a primary reason why it is so active in aquatic environments. The solubility varies inversely with temperature and at temperatures common in nature, carbon dioxide is much more soluble than oxygen.

Carbon dioxide in natural waters may be obtained from the following sources:

1. Bacterial decomposition of organic matter.

2. Respiration by plants and animals. Plants contribute much more at night when photosynthesis is not occurring.

3. Groundwater seeping into surface water.

4. Chemical reactions between acids and various compounds of carbonates.

5. Atmosphere.

6. Rainfall.

Values exceeding 20 mg/l of free carbon dioxide generally may be considered as harmful to fishes, but lower values may be just as harmful in water with oxygen content of less than 3-5 mg/l. Also, fishes may suffer or die if exposed too quickly to large changes up or down in CO_2 concentrations.

High concentrations of free CO_2 are usually accompanied by low values for dissolved oxygen, thus compounding the problems for fishes. The differences in carbon dioxide and oxygen levels of a pond or lake result mainly from two processes:

1. Carbon dioxide is used by photoplankton to create food and oxygen when sunlight is reaching the water, with CO_2 becoming least abundant in later afternoon.

2. The CO_2 demand stops when the sun sets because, without sunlight, phytoplankton stop manufacturing food and oxygen. During the night, plants and animals continue to use oxygen and expel CO_2. This increases CO_2 until dawn when it reaches its highest concentration and dissolved oxygen is normally reaching its lowest concentration of the day.

Carbon dioxide problems in ponds can be solved by aeration. Refer to the section on dissolved oxygen for recommendations on aeration.

Alkalinity

Alkalinity refers to the types and amounts of compounds which cause a change in the pH of a solution toward the alkaline side of the pH range. It refers to the presence of certain negatively-charged ions (anions): carbonate ($CO_3^=$), bicarbonate (HCO_3), and hydroxide (OH).

Carbonates and bicarbonates "buffer" the water, tending to hold the pH constant, while hydroxides tend only to make the pH high. Alkalinity often reflects the activity of calcium carbonate.

Carbon dioxide will combine with water to form carbonic acid which in the absence of appreciable alkalinity will depress the pH of water. If calcium carbonate is present, it will combine with the carbonic acid to form calcium bicarbonate and result in very little change in pH. Therefore, alkalinity helps prevent large changes in pH by neutralizing acid in the water.

Four forms of alkalinity may be measured chemically:

1. Bicarbonate

2. Normal Carbonate

3. Hydroxide

4. Total alkalinity (all of the 3 above forms and the one most commonly measured in pond management.)

When testing for alkalinity, a quantity of strong acid is added to the water in the presence of a proper indicator. The amount of acid needed to convert any carbonate or bicarbonate present to free CO_2 is a measure of the $CO_3^=$ and HCO_3 in solution.

Total alkalinity measurements of pond waters may be as high as 300-400 mg/l of calcium, depending on geologic conditions of the area. The most common values are between 45 and 200 mg/l with little direct effect on fishes. However, ponds with total alkalinities below 45 mg/l are

generally biologically less productive due to inadequate carbonate content and poor buffering ability. These qualities make the water less suitable for the production of phytoplankton and other vital links in the food chain of the pond.

Hardness

Hard waters are generally considered as waters that need rather large amounts of soap to produce a foam or lather. Soft water produces lather readily. Hardness refers to the presence of certain cations (positively-charged ions) which cause soap to precipitate and be useless. The main hardness causing cations include: calcium, magnesium, manganese, ferrous iron, and strontium. Anions (negatively-charged ions) which are usually found with these cations are: bicarbonate, sulfate, chloride, nitrate, and silicate. Total hardness is a measure of the combined amount of all of these compounds in solution.

Hardness in water results from contact with the soil and rocks. Therefore, the geological nature of rock formations with which water has contacted reflects the hardness of the water. In Arkansas, ponds in the Coastal Plain, Boston Mountains, Arkansas River Valley and Ridges, and the Ouachita Mountains normally have soft water. The Ozark Mountains and wells in the Delta tend to have harder water.

Classification of water by degree of hardness is expressed in milligrams per liter (mg/l) of $CaCO_3$ equivalents as follows:

0 - 75 mg/l	-	soft
75 - 150 mg/l	-	moderately hard
150 - 300 mg/l	-	hard
300 up mg/l	-	very hard

In soft waters, phytoplankton growth (the base of the fish food chain) is limited by low calcium concentration and, at times, inadequate amounts of carbon dioxide and bicarbonate. Soft water is poorly buffered which allows the pH to vary greatly throughout the day. These conditions severely restrict fish production.

pH

Many fishes tolerate wide ranges in pH (4.6 to 11), but their growth and reproduction are usually best in waters with pH between 6.5 and 9.0. A pH of 4.0 or lower is often lethal to pond fishes. Bass and bluegills seldom spawn if the pH is below 5.0, and growth is usually slow when pH is between 5.0 and 6.5.

Acid waters (low pH) do not respond well to fertilization and thus tend to have poor fish production. Phytoplankton are similar to clover in that they need a neutral to alkaline medium in which to grow.

Ideally, soil in the basin of new ponds should be treated prior to impoundment with enough agricultural limestone to bring the soil pH to 7.0 (neutral). An average application would probably be about two tons per acre on the pond bottom. If the pond is drained for any reason, lime should be applied again at the original rate.

Prolonged reactions with the bottom layer of water usually cause the bottom soils to become increasingly acid as the pond gets older. Acidic bottom soil is less productive of fish food organisms. Liming of

crop fields, pastures, and hay fields in the pond's watershed can also add lime to the pond. This may decrease the need for large lime applications in the pond periodically. Soil tests should be made every 5 years and limed accordingly. However, as a rule, one to two tons of agricultural lime per acre should be added to a pond every 5 to 7 years.

Soils deficient in calcium (lime), especially sandy soils and sandstone areas, can lead to excessive acidity in pond water. Soils containing sulfides may also cause problems when disturbed during pond construction. The leaching of sulfuric acid from such areas may lower the pH of pond water enough (below 4.0) to kill fish.

The pH of a pond may vary greatly in a matter of hours, as plants remove CO_2 for use in photosynthesis. The pH may vary from 5.5 or 6.0 in the morning (due to CO_2 buildup during the night) to 10 or 10.5 in the afternoon as CO_2 is used in photosynthesis. This does not mean that this condition needs to be treated as long as the pH decreases to normal levels in the evening.

Ponds having a pH that does not get above 6.5 at any time of the day should be treated with agricultural lime. Use one to two tons of lime per acre. Repeat when water tests show that the pH is getting low again.

Extremely acid conditions (pH below 4.0) <u>may</u> be indicated in ponds by very clear water with a bluish cast. Such environments should not be stocked with fish until the water is tested and conditions are corrected, if problems exist.

Ponds with severe acidity problems should be treated with hydrated lime. Applications of 50 pounds per acre should be made in conjunction with water tests to avoid getting the pH too high. Periodic retreatment will usually be needed depending on the amount of water passing through the pond. Hydrated lime will usually be effective for about one year in the average pond.

The best time to apply lime is before the pond is filled with water. A soil test would indicate the amount of lime needed. However, in most cases pond treatments occur after ponds are filled. Lime should be applied in these ponds during late fall and early winter so lime will react with water and bottom muds before fertilization begins in the spring.

Applications of lime during the summer will precipitate algae and phosphorus, thereby clearing the water which may encourage aquatic weed growth.

Once ponds are properly limed, further application of lime is needed only to replace that lost to outflow. Ponds with slight to moderate outflow will need to be relimed every 5-7 years.

If pond water is excessively alkaline (pH 10 or above) for extended periods, treat with 5 pounds of aluminum sulfate per acre foot.

If acid drainage into a pond is identified as a significant problem, construction of a diversion ditch near the pond's edge, or at a suitable uphill location, can divert the acidic water away from the pond.

FERTILIZATION OF FARM PONDS

A proper fertilization program in most Arkansas ponds will increase fish production by 4 to 5 times. This increase is due to increased production of microscopic plants after additional nutrients from the fertilizer are added. These microscopic plants provide food for microscopic plants and animals which are eaten by insects and small fish. The insects and small fish provide food for larger fish in the pond.

The increased production of microscopic plants and animals will cause the water to develop a green or brown color within 3 to 7 days after adding fertilizer. At this point, the pond is said to have a "plankton bloom." A desirable "bloom" will limit the vertical underwater visibility to 12 to 24 inches, thereby helping to shade the sunlight from undesirable rooted plants and filamentous algae on the pond bottom. The vertical underwater visibility can be easily checked with a white object (water-proof paper, plastic, or metal) attached to the end of a calibrated stick. The depth of water at which the white material can no longer be seen is the vertical underwater visibility.

Inorganic rather than organic fertilizer is most often used for increasing fish production in farm ponds in the United States. The use of organic fertilizers such as manure and cottonseed meal can encourage the growth of undesirable filamentous algae and can also cause oxygen depletion problems.

When and How Much to Fertilize

The amount of fertilizer needed to maintain a desirable bloom will vary among ponds due to differences in the amount of natural fertility in the pond water. Because of such variations, some ponds will require only six applications per season while others will need as many as sixteen applications. Fertilizer should not be used in ponds where artificial food is used regularly. Artificial food will take the place of fertilizer, eliminating the need for it.

Under most conditions, fertilization should begin in the spring after the water has warmed to about 65°F. The addition of fertilizer to colder water will often stimulate the growth of filamentous algae more than phytoplankton which will nullify the benefits being sought from the fertilizer.

Begin fertilizing by adding eight pounds each of nitrogen and phosphorus and two pounds of potassium per acre. This quantity of fertilizer can be added to the pond by applying one of the following combinations.

1. 100 pounds of 8-8-2
2. 40 pounds of 20-20-5
3. 100 pounds of 6-8-4, plus 5 pounds of Ammonium Nitrate*
4. 25 pounds of Ammonium Nitrate, plus 40 pounds 20% Superphosphate, plus 4 pounds Muriate of Potash.
5. 66 pounds of 6-12-12, plus 12 pounds of Ammonium Nitrate.
6. 100 pounds of 6-8-8, plus 6 pounds of Ammonium Nitrate.
7. 100 pounds of 4-8-8, 12 pounds of Ammonium Nitrate.
8. 66 pounds of 4-12-4, plus 15 pounds of Ammonium Nitrate.
9. 100 pounds of 8-8-8
10. 50 pounds of 15-15-15
11. 50 pounds of 16-16-4

Nitrate of soda or ammonium sulfate may be substituted for ammonium nitrate by using twice the prescribed rate. Nitrate of soda is better in soft water because it does not lower the pH as ammonium sulfate may do.

After this initial application, begin checking the vertical underwater visibility of the pond with a calibrated stick to which a white disc is attached. Any time the underwater visibility becomes greater than eighteen inches, add fertilizer at the same rate as applied initially. Discontinue fertilization when the water temperature drops below 65°F or roughly from the first week in October to the first week in March depending, of course, on weather conditions. Begin the same fertilization program each spring.

Many ponds need fertilizer three to six times at one- to two-week intervals each spring to maintain fertility. During the remainder of the fertilization season, ponds usually need to be fertilized only once per month.

Experimenting With Fertilizers To Reduce Costs

In order to decrease the cost of fertilization, the pond owner should experiment to determine if a less expensive formulation will provide a desirable bloom. In recent preliminary studies at Auburn University, the use of 40 pounds per acre of 5-20-5 fertilizer per application has provided equally effective results in producing and maintaining a desirable plankton population as the addition of 40 pounds per acre of 20-20-5 per application. If the 5-20-5 does not produce desirable results, use the 20-20-5.

During the hot summer months, dense blooms of blue-green algae often appear in ponds. These plants are able to utilize nitrogen from the atmosphere and there may be little need for adding this element. For ponds with such blooms or for ponds to which a proper fertilization program has been applied for three or more years, it may be possible to maintain a plankton bloom by adding only phosphorus. In such ponds, add 40 pounds of superphosphate or 18 pounds of triple phosphate per acre per application. If a plankton bloom does not develop in the spring soon after adding the phosphate, then switch back to the formulation used in previous years. Once a bloom forms, attempt to maintain this bloom by using only phosphate. If this method fails, revert back to the same fertilizer used in previous years.

Applying Fertilizer

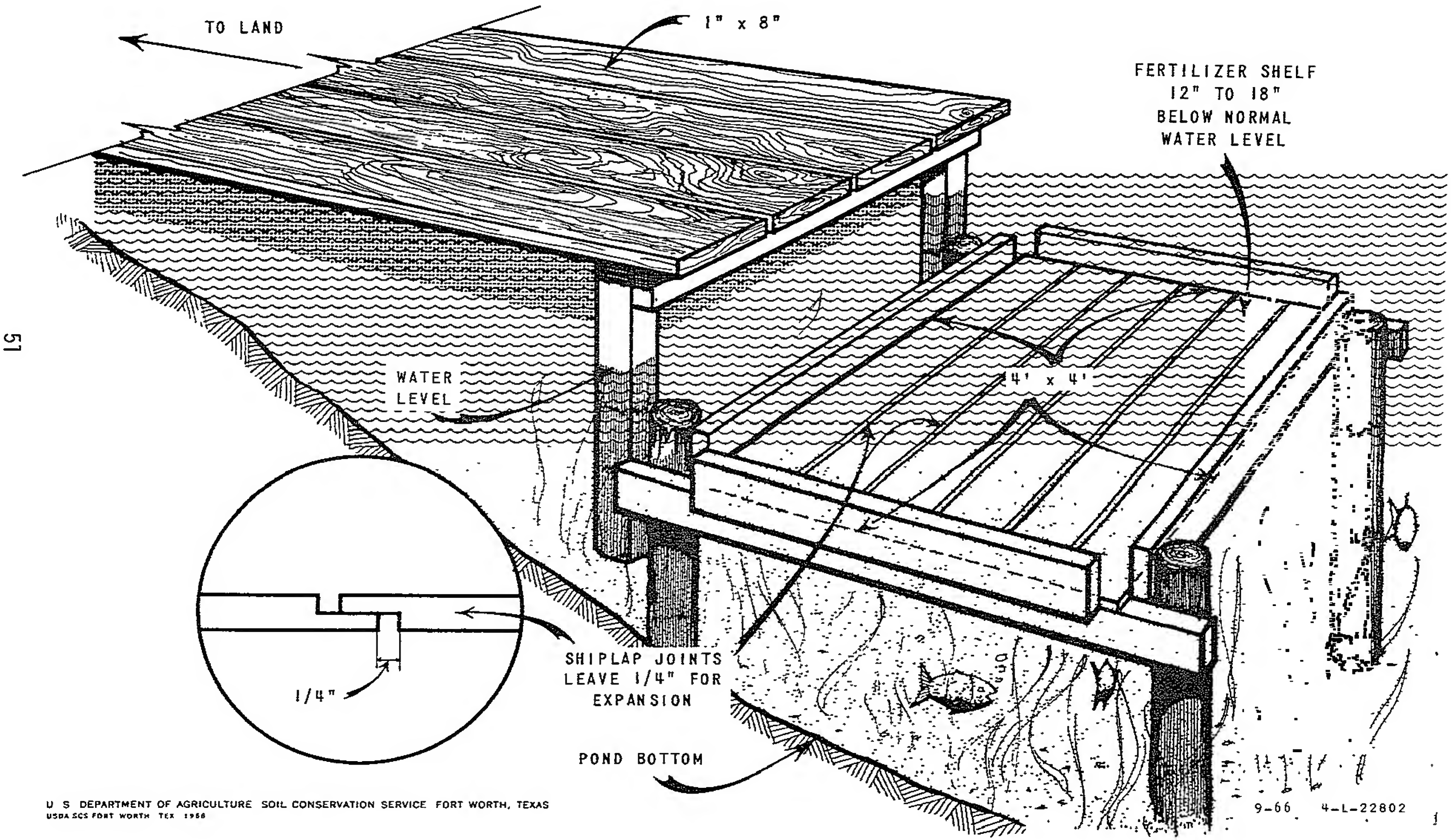
Commercial fertilizer may be added by broadcasting over water which is less than four feet deep or by placing whole bags at intervals around the pond's edge. These bags should be opened to allow wave action to distribute the dissolved nutrients.

A third method is to support the fertilizer above the bottom to prevent the rapid tie up of phosphorus in the bottom soil. This may be accomplished by the use of stationary platforms or floating devices that are free to move around the pond. This method allows the nutrients to slowly dissolve into the water and a more even bloom to be maintained, often with less fertilizer.

A fertilizer platform should be about four feet square and from one to two feet underwater, as shown in the drawing on the following page. One platform for every five surface acres of water is sufficient to provide distribution of nutrients.

FIGURE 8

A TYPICAL FERTILIZER PLATFORM



U S DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE FORT WORTH, TEXAS
USDA SCS FORT WORTH TEX 1966

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FERTILIZATION PROBLEMS

Once a fertilization program is begun it should be continued. Discontinuing fertilization will result in a negative reaction by the fish population. As the quantity of plankton is increased by fertilizer, the total weight of fish expands accordingly. Discontinuing fertilization causes a reduction in plankton resulting in not enough food for too many fish. The fish population may respond by becoming stunted.

In some ponds, it is difficult to achieve and maintain a plankton bloom by fertilization. The four most common causes of this problem are soft water, excessive amounts of water flowing through the pond, muddy water, and the presence of rooted aquatic vegetation.

Soft Water

Ponds with water softer than 20 milligrams per liter total hardness will often not develop adequate plankton blooms when fertilizer is added. Agricultural limestone (calcium carbonate) can be used to correct this problem

Before a pond is built, the pond owner should have the soil tested and lime the pond bottom according to recommendations. If water is already present in the pond, lime can be added to the water, preferably during winter months by spreading the limestone over the entire pond area or around the shallow water edges. In the past, many fish pond bulletins have recommended applying 2,000 pounds per acre of lime to all farm ponds. However, some ponds will require 100 pounds per acre of lime while other ponds will require 4 to 5 tons or even more. Dr. Claude E. Boyd (Auburn University, Auburn, Alabama) has devised a technique to determine exact lime requirements for ponds already filled with water. In order to use Dr. Boyd's technique, 12 to 15 mud samples must be collected from different locations along the pond bottom in water greater than 3 feet deep. The mud samples are mixed together and shipped in a 1-quart container to a laboratory for soil analysis.

Excessive Water Flow

Water must remain in a pond for at least 3 or 4 weeks if fertilization is to provide desirable results. If water moves through the pond at a faster rate, nutrients are washed away and a desirable plankton bloom cannot be maintained. The detention time of water should be considered when first selecting a pond site. If there are no more than 6 to 15 acres of drainage area for each surface acre of water, excessive water flow should not be a problem unless a perennial flowing stream or spring passes through the pond.

The detention time of water in a pond can be increased by diversion of excessive water, enlargement of the pond, or construction of another pond upstream from the existing pond. A bottomwater release can also be used to remove excessive water flows and reduce the loss of nutrients.

Muddy Water

Muddy water can reduce fish production and general quality of a pond in a number of ways. It will shade out sunlight which is necessary to obtain a phytoplankton bloom, thus decreasing production of fish food organisms. Muddy water can conceal forage fishes from predatory fish

such as bass which feed by sight. The resulting process of sedimentation can suffocate fish eggs either by coating the eggs, which excludes oxygen, or by reducing the flow of oxygenated water over the eggs. Continued sedimentation can greatly reduce the pond's volume and may eventually fill the pond.

The average total weight of fish produced in a pond may be five times greater in clear ponds than in muddy ponds. If resulting from floodwater, muddy water may replace fertilized water that washes out through the spillway.

A pond owner should strive to obtain good plant cover on the entire watershed of his pond to hold soil in place and to absorb more rainfall to decrease flooding. Grazing and cultivation in the watershed should be controlled. Livestock should not be allowed in the pond, if the pond owner hopes to prevent muddy water, eroded banks, and organic pollution in the pond.

Wind action along the shoreline may tend to muddy water and should be combatted by good plant cover along the banks to the water's edge or by riprapping problem banks where vegetation is not the answer.

Large populations of bullheads or common carp can cause much turbidity throughout a pond. Such populations should be removed and the pond restocked with the recommended species.

If none of the above causes are applicable to a turbid pond, the problem may be caused by suspended clay particles that will not settle. These suspensions are composed of very fine particles with similar electrical charges which repel each other and do not settle.

Various substances may be added to the pond to make these clay particles settle:

1. Agricultural gypsum is very effective and fast in clearing muddy water, but relatively large amounts may be required. Although as little as 100 pounds of gypsum per acre may clear the water, up to 500 pounds per acre-foot of water may be needed. The water should become clear within one week after gypsum is applied. Gypsum can cause a depression of pH and should not be used in waters with a pH below 6.5. Resume normal fertilization after the water clears.

2. Aluminum sulfate has proven effective in clearing muddy water when used at a rate of 15 to 25 pounds per acre. If water is not clear after two days, add another 25 pounds per acre. Since aluminum sulfate will lower the pH, about 50 pounds per acre of hydrated lime should also be added to the pond if the pH of the water is below 7.0 before treatment.

3. Muddy ponds can usually be cleared by applying 75 pounds of cottonseed meal and 25 pounds of superphosphate or equivalent per surface acre. Apply over the entire pond at 2 to 3 week intervals until the water clears.

   During summer, use only superphosphate at the rate of 50 pounds per acre for clearing muddy water. During hot weather, cottonseed meal may use enough oxygen in its decomposition to cause an oxygen shortage.

4. Green hay or dry straw will promote bacterial growth which causes suspended clay particles to clump and settle. Seven to ten bales of hay or straw per acre may be scattered along the shallow edges, after breaking the bales into blocks. Repeat this treatment after ten days, if necessary. Do not use hay in hot weather; its decay may cause a serious loss of oxygen. Hay, as well as the cottonseed meal, should be added to a pond only during early spring, late fall, or winter when water temperatures are relatively cool.

5. Hydrated lime may also be used to precipitate clays in suspension. It should be spread thoroughly over the pond at a rate of 35 to 50 pounds per acre.

Rooted Aquatic Plants

If rooted aquatic plants are already well established in a pond, they will use all nutrients added to the pond by fertilization and no phytoplankton bloom will be established. Once such plants are removed, fertilization will produce a plankton bloom which will shade the rooted plants and prevent their reoccurrence. Refer to the section on CONTROL OF AQUATIC PLANTS.

MISCELLANEOUS POND PROBLEMS

Objectionable Flavors in Fish

Occasionally fish caught from certain ponds have objectionable flavors. Blue-green algae, chara, or other aquatic plants may cause this. It may be caused by a pollutant draining into the pond.

When this problem arises, a thorough examination of the pond should be made to identify any sources of pollution or vegetation which may be the cause. When significant pollution of the pond is found, steps should, of course, be taken to stop it or at least divert it from the pond, whether it is directly associated with the taste problem or not. Such things as animal wastes, septic tank drainage, or insecticides may result directly or indirectly in killing fish or exposing them to diseases.

Hydrated lime may remove objectionable flavors from pond fish as well as clear muddy water. It should be spread thoroughly over the pond at a rate of 35 to 50 pounds per acre. Two applications should be made at two to three day intervals. Check the fish in two to three weeks.

Muskrats

Muskrats dig burrows about a foot below the water surface and slope them upward into the bank for four to six feet so that their den chambers are above the water line. This may cause serious damage to the dam and the pond, especially if a number of muskrats are involved and if some of them decide to dig farther into the dam than usual.

Muskrats can be discouraged by removing their sources of food, such as cattails and other emersed vegetation along the shoreline. Their activities may also be limited by keeping the pond banks mowed.

Muskrats can be trapped during the open season. They may also be discouraged by drilling holes at three or four foot intervals on the upstream face of the dam about two feet from the water's edge. Extend the holes about two feet below the water line. Place four to five ounces of creosote, calcium carbide, or naphthaline in each hole and seal the holes with soil or sod. When a digging muskrat reaches the treated zone, he will usually leave the area.

Chicken wire placed above and below the water line along the dam also prevents muskrats from digging.

Crayfish

Any insecticide placed in a burrow and sealed with sod or soil will usually kill crayfish, but since most insecticides are toxic to fish, care should be taken not to place any in the pond.

The following recipes can be used to make simple crayfish poisons:

1. Dissolve one dozen mothballs in one gallon of kerosene, add two gallons of warm water and a tablespoon of detergent. Place a cupful of this mixture in each burrow and seal.

2. Add eight teaspoons of lye to one gallon of water. Pour one cup of this solution into each burrow and seal.

3. Dissolve four ounces of chloride of lime in three quarts of water. Pour one to two ounces of this solution in each burrow.

Remember that not all crayfish are harmful to dams, and most crayfish species are important food for bass.

Turtles

Turtles are common in Arkansas ponds and they can become a nuisance by stealing baits and fish from stringers. However, the total diet of most turtles is usually about 80 percent vegetable matter and often less than three percent fish. Turtles do not harm fish populations.

Some kinds of turtles, especially snappers and softshells, are good to eat and the pond owner may wish to trap them. An efficient trap can be constructed out of scrap lumber and screenwire or chicken wire. Use this material to construct a box large enough to hold several turtles about 12 inches in diameter. Attach ramps on two sides of the box and set in shallow, weedy areas of the pond. Bait with fish or fish heads, chicken entrails, watermelon rind, or meat scraps placed inside the box. Traps should be checked daily to remove turtles, especially if they are to be eaten. Turtles may be trapped from spring to early fall.

Short, stout, bank lines with large hooks and no sinkers may be baited with tough neck meat to catch turtles. A dozen of these lines have been used to control snappers in a 1.5 acre pond in only two to four nights.

Fish Kills

1. Winter kill - Oxygen supply under ice depends on the passage of light and the production of oxygen by tiny plants through photosynthesis. If snow covers the ice, sunlight can not penetrate and the plants produce no oxygen. Oxygen is being used by decay processes and by respiration of fishes and other aquatic animals. If snow remains on the ice long enough, oxygen is depleted and the fish suffocate. This is most likely in fertile, shallow, weed-filled ponds.

Winter kills may be prevented by deepening the pond and removing fertile, organic matter. Removing the snow cover from the ice will allow light to penetrate and photosynthesis to take place. Chopping holes in the ice will not help.

2. Summer kill (aquatic plant die-off) - Aquatic plants often die during summer and use the oxygen in the water as they decay. Whether natural causes or herbicides kill these plants, fish kills may result if enough oxygen is used in the decaying process. This type of kill almost always occurs about sunrise when the dissolved oxygen is at its low point of the day.

Rooted aquatic vegetation and algae should be controlled so it never becomes dense. If it is dense, treat only a part of it at any one time and allow that part to decay before more treatment. Wait at least seven days before treating another part of the pond.

3. Summer kill (temperature) - Shallow ponds may have water temperatures as high as 85 to 95°F during summer. Water holds very little oxygen when its temperature is above 80°F. Dissolved oxygen may disappear entirely during the night if the preceding day was calm.

To help prevent this, deepen the pond so that about 25 percent of the area is seven to ten feet deep or deeper.

4. Organic pollution, pesticides, industrial and mining wastes - Ponds can easily become polluted from barnyards, feedlots, silos, sewage drainage, herbicides, fungicides, and insecticides used on farm crops, and drainage from industrial and mining wastes. Many of these pollutants are washed into ponds by rains and their concentrations may easily become large enough to cause fish kills from lack of oxygen or poisoning.

Such kills may be prevented by using drain tiles, diversion ditches, levees, and land leveling to divert pollutants, or allow them to filter into the soil. Pesticides should not be applied near ponds or on windy days.

5. Natural mortality - The natural resistance of fish to disease is lower in the early spring than at any other time of the year. A few large fish may be found along the shoreline in the spring, since larger fish seem to be more susceptible to disease than smaller fish, or such death may just be due to old age. Most warm water fish in the southern United States do not live more than four to eight years.

Fish Diseases and Parasites

Fish are susceptible to a wide variety of diseases, parasites, and abnormal growths. They appear and spread most frequently when nutrition is low and when fish are crowded, as in a fish hatchery or fish farm. Diseases often occur in spring when the fish are usually in poor condition. Fish diseases usually do not spread rapidly in the normal farm pond environment. Most fish diseases and parasites are not harmful to man, if the fish are properly cleaned and cooked before being eaten.

The following pamphlet, "What's Bugging That Fish," describes some of the major, warm-water fish diseases and parasites. Even though it was prepared for fishermen in Nebraska, this pamphlet is still quite applicable to fishermen and pond managers in Arkansas.

WHAT'S BUGGING THAT FISH?

AN ANGLER'S GUIDE TO FISH DISEASES AND PARASITES

A contribution of Federal Aid in sport fish restoration
Project F 4-R Nebraska

Prepared by Nebraska Game and Parks Commission in cooperation with Monte A Mayes Harold W Manter Laboratory University of Nebraska State Museum

Of the more than 1 000 species of North American freshwater fish parasites only a few are known to infect man and those rather rarely. The broad fish tape worm, *Diphyllobothrium latum* is the most common fish parasite that infects man in North America but its range is very limited in the United States, and has not been found in Nebraska. This tapeworm as all other fish parasites is killed by ordinary cooking methods. Hot smoking methods also kill fish parasites but some survive the cold smoking procedures.

Dr Glenn L Hoffman, Parasitologist
U S Fish and Wildlife Service
Eastern Fish Disease Laboratory

Fishing is one of the most popular participation sports in Nebraska. Each year, close to a quarter million fishing permits are issued to residents and visitors. And, the anticipated outcome of any fishing trip for novice or veteran is a lip-smacking fish fry.

Occasionally though anglers may hook a fish that shows signs of infection or parasitism. Before throwing the fish away check it carefully. Most are healthy, and studies have shown that very few fish diseases can be transferred to man. Virtually all fish are okay when thoroughly cooked smoked, or frozen.

This leaflet should help identify most of the conditions of those occasional fish that show signs of disease or parasitism. Generally, a fisherman will see the results of an infection or parasite rather than the organisms themselves. Consequently, these visual characters or signs are cited to assist in identification of the infective agent.

Parasitism is a way of life. It exists in the plant kingdom and in practically every major group of the animal kingdom. A parasite is an organism that lives in or on another larger organism of a different species (the host) from which it derives nourishment. Depending upon the particular parasite, the relationship may be temporary or permanent. Some parasites can cause disease and thus become economically important. Damage can be caused in a number of ways—by blocking passages, by penetrating walls, by diverting part of the food supply, by allowing secondary infections and by other means.

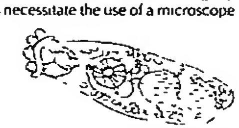
There are nine major groups of parasites and disease-causing organisms found in Nebraska fishes. Parasites seldom harm their hosts, except when they are quite numerous or the fish is under stress from some other cause.

Viruses and bacteria cause several diseases. While these minute microorganisms cannot be seen with the naked eye an angler can spot the symptoms, which range from "pop-eye" to swollen bloody fins.

Commonly found in fresh water, **fungi** are thread-like plants that lack chlorophyll. These parasites do not attack normal, healthy fish. However, if a fish is injured and its protective mucous coat is removed, a fungus growth could eventually cause its death.

Small, single-celled organisms called **protozoa** may cause a variety of fish diseases. They can be found in cysts on the gills, embedded in the flesh or free on the surface of the body. Some protozoa can be seen with a magnifying glass, while others necessitate the use of a microscope.

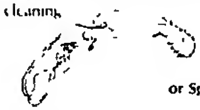
Trematode or Fluke



The larval stage of several **trematode worms or flukes** is usually found in cysts in the flesh or on the internal organs. However they can also occur in the eye and other parts of a fish. Although potentially harmful to some fish-eating animals flukes are not dangerous to man if the fish is prepared properly. Adult flukes can also be found in many organs of a fish but they will seldom be seen unless one specifically looks for them.

Cestode or Tapeworm

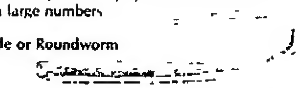
A variety of larval and adult **cestodes or tapeworms** infect many Nebraska fishes. Larval tapeworms are found in cysts on or in the internal organs or free in the body cavity. Adult tapeworms inhabit the intestines and these white worms can be seen when an intestine is accidentally slit in cleaning.



Acanthocephalan or Spiny-headed Worm

Fishermen will seldom see an **acanthocephalan or spiny-headed worm.** The adults normally live in the intestine, although one species may sometimes be found in the body cavity with its head buried in the intestinal wall. Larval acanthocephalans occur as white cysts attached to the internal organs. While not harmful to man spiny-headed worms may cause injury to the intestine of a fish if present in large numbers.

Nematode or Roundworm



One of the most common parasites found in fish **nematodes or roundworms** sometimes occur in great numbers. The larval stage may be found in cysts or coiled on or in the internal organs. Adult roundworms generally attach themselves in the intestine, although some may coil under the skin in the head area or on the fins.

Leeches may be external blood-feeding parasites. They may adhere to almost any part of the body but seem to prefer the fins. Leeches will leave small circular wounds, which may become infected with bacteria or fungi. They do not harm the flesh and can simply be discarded when a fish is cleaned.

A highly diversified group of parasites **copepods (small crustaceans)** are found embedded in the flesh attached to the gills or mouth or moving freely over the surface of the body. If they occur in large numbers some species can kill young fish. Other species open wounds in the body making the fish susceptible to bacterial or fungal infection.

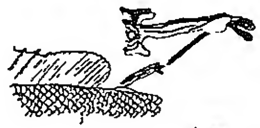
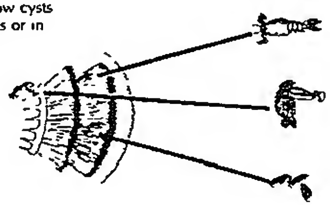
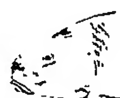
HELPFUL HINTS

After examining a fish and removing the useable flesh care should be taken in disposing of the remains. Don't throw the body back into a lake or stream. Some parasites can continue their life cycles if they are returned to water. If fishing on a state-operated area follow posted instructions or place the remains in the drums supplied for waste. On private land ask permission to bury the remains. If the fish is cleaned at home dispose of the fish in the normal manner.

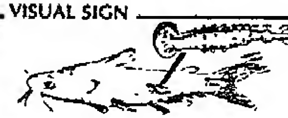
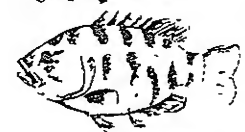
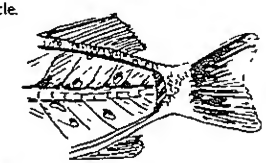
HANDLING FISH

Fish secrete a protective mucous coating which helps prevent fungal and bacterial infections. If this mucous coat is damaged the fish becomes much more suceptible to infection.

Size limits are now in effect on some fish species in Nebraska and it behooves anglers to take extra care when returning under size fish to the water. The mucous coat probably will not be harmed if a hook is removed while the fish is still in the water or if the angler wets his hands before handling the fish. In addition the fish should be released gently after the hook is removed rather than tossed into the water.

VISUAL SIGN		CAUSE/RECOMMENDATION
Found Externally		
1 Fish popeyed scales puffed with fluid (dropsy) Bloody wounds blood under scales		**Various Bacteria** (such as *Aeromonas* sp*) Commonly found in water, *Aeromonas* normally does not infect fish, unless they have undergone some stress. Fish with severe popeye or dropsy probably will not bite, but can be seen dead or in distress along the shore. In some cases, open bloody wounds can result from the bacterial infection. **Edible, if wound is superficial; remove infected tissues and cook well. If popeye is indicated, destroy fish.**
2 Red pustule on or near base of fins, thread-like body may protrude from the wound		**Anchor Worm** (*Lernaea* sp.) This copepod buries only its anchor-shaped head into a fish's flesh. The remaining portion will hang free from the wound, where a red inflamed pustule may form. This parasite may drop off, leaving only the inflamed area. **Edible. Removed inflamed area, clean and prepare as usual.**
3 Bloody area on body under the scales		**Fish Louse** (*Argulus* sp.) This rarely seen copepod leaves a fish soon after it's removed from the water. It feeds on the blood by piercing the skin, destroying the protective mucous coat in the process. Thus, secondary infection from bacteria or fungus can result. **Edible. Clean and prepare as usual**
4 Tiny mobile white spots on the skin		**Ich** (*Ichthyophthirius* sp.) The most common protozoan encountered by fishermen, Ich appears as mobile white spots or clusters on the skin or gills. It burrows under the skin and may cause surface lesions. Individuals can be seen with a magnifying glass. **Edible. Clean and prepare as usual.**
5 White or yellow cysts or sacs on gills or in mouth		A. (*Ergasilus* sp.) When numerous, these copepods can kill young fish. Their presence is indicated by V-shaped white egg sacs on the inner edges of the gills. **Edible. Clean and prepare as usual.** B (*Achtheres* sp.) Larger than *Ergasilus*, this copepod attaches itself in the mouth or to the inner surface of the gills. *Achtheres* has a short plump body with armlike appendages that cling to the fish. **Edible. Clean and prepare as usual.** C. **Yellow Grub** (*Clinostomum* sp.) This larval fluke forms cream-colored cysts on the gills and under the skin in the mouth. It can easily be seen with a magnifying glass if cyst is broken. **Edible. Clean and prepare as usual.**
6 White pustules under skin or scales		**(Myxosporidia).** The white cysts created by Myxospondia hold thousands of the microscopic protozoans. While certain species cause some important diseases in fish, none have been found in Nebraska. **Edible. Clean and prepare.**
7 Patches of fuzzy grey-white mat on body and gills		**Water Fungus** (*Saprolegnia* sp.) Usually found on fish injured by improper handling or other cause. When established, Water Fungus can kill a fish by completely covering it. **Edible. Skin fish; remove infected area and adjacent flesh; prepare as usual.**
8 Grey-white slime on the skin		**Columnaris Disease** (*Condrococcus columnaris*) This bacterial infection may be found on catfish, trout and possibly other species. Frayed fins and bloody wounds are other indicators. **Edible. Clean and prepare as usual.**
9 Black spots under the skin or in the flesh.		**Black Spot** (*Neascus* sp.) The easiest disease to recognize. Black Spot is caused by larval flukes burrowing under the skin. Appearing as small round black spots, the cysts may also be found in the flesh. **Edible. Skin and prepare as usual**
10 Eye deformed; fish apparently blind		**Eye Fluke** (*Diplostomulum* sp.). These tiny larval flukes will not be seen. They live in the fluid of the eye and eventually cause blindness. Eye may be opaque or shrunken. **Edible. Clean and prepare as usual.**

* sp = species

VISUAL SIGN		CAUSE/RECOMMENDATION
11. Undulating worms attached to body, fins, gills and mouth		**Leeches.** Conspicuous, blood-feeding external parasites, leeches produce a small circular wound that remains even though the leech moves or drops off. **Edible. Clean and prepare as usual.**
12 Red thread-like worms extending from the anus		**Round Worms** (*Camallanus* sp.) Various roundworms are found throughout the intestine. The species that lives in the lower large intestine will occasionally extend from the anus. **Edible. Clean and prepare as usual**
13 White to pink thread-like swelling on head or fins		**Round Worms** (*Philometra* sp.) Normally found on carp, buffalo, and suckers, this adult roundworm lives just under the skin. **Edible. Clean and prepare as usual**
Found in the Flesh		
14 White or yellow cysts imbedded in the muscle.		**Yellow Grub** (*Clinostomum* sp.) Cream colored cysts found in many parts of the body contain larval flukes that become adults in birds. Numerous at times, the Yellow Grub will emerge if cyst is broken in water. **If practical, remove cysts from flesh, clean and prepare as usual. Otherwise discard entire fish** **White Grub** (*Hysteromorpha* sp.) Smaller and lighter colored than the Yellow Grub. These larval flukes are most often found in catfish. **Use same as above**
15. Sandy flesh in walleye		**Unknown.** An unusual problem apparently found only in walleye. Fish show no external symptoms or abnormal behavior. The rough sandy flesh is found in varying intensity when fish is filleted but the flesh is always somewhat discolored. **DO NOT EAT. Wrap fish in plastic or foil (do not freeze) and notify nearest Game and Parks Commission office.**
Found Internally		
16 Large white flat worm in the body cavity		**Tapeworm** (*Ligula* sp.) This larval tapeworm is found free in the body cavity of minnows, carp, sucker and some other fish. It is uncommonly large and may create an abdominal bulge. **Edible. Clean and prepare as usual**
17 Coiled (like a watch spring) worm encysted on the internal organs		(*Contracaecum* sp.) Found on the internal organs or the wall of the body cavity, these larval roundworms are immobile. They become adult in fish-eating birds. **Edible. Clean and prepare as usual.**
18 Round transparent cysts on the internal organs.	 Heart	**White Grub** (*Neascus* sp.) These larval flukes occasionally occur in quite large numbers. **Edible. Clean and prepare**
19 Irregular white cysts in or on the internal organs		**Larval Spiny-Headed Worm or Larval Tapeworm.** These cysts are larger, whiter and not as round as those described in No. 18. **Edible. Clean and prepare as usual**
20 White thread-like worms lying on or moving through the internal organs		**Larval Tapeworm.** Some tapeworms are not found in cysts. Numerous worms may infect the ovaries of bass. **Edible. Clean and prepare as usual. Roe can be cleaned by removing worms with tweezers before preparing**
21 Tiny gold brown cysts on the internal organs	 Liver	**Larval Roundworm.** Often found in great numbers, these cysts will give a sandy appearance to a fish's innards. **Edible. Clean and prepare as usual**
22 White or orange worm in body cavity attached to the intestine		**Spiny-Headed Worm** (*Pomphorhynchus* sp.) Since most adult acanthocephalans live inside the intestine, they are not seen by fishermen. However this species can be found lying in the body cavity with its head buried in the intestine. **Edible. Clean and prepare as usual**
23 White, undulating worms emerging from ruptured intestine		**Intestinal Worms (Adult Helminths)** Adult flukes, tapeworms, roundworms and spiny headed worms will not normally be seen by fishermen unless the intestine is accidentally cut in cleaning. **Edible. Clean and prepare.**

AQUATIC PLANTS

As discussed earlier, aquatic plants in the form of miscroscopic algae form the basic food reserve for all forms of aquatic animal life. Only plants can convert solar energy into chemical energy in stored form.

However, overabundant growths of aquatic plants are undesirable because they may lead to a number of problems:

1. They hide small bluegills and other forage fish from bass which can lead to slower growth of bass and possibly overpopulation and stunting of sunfish.

2. They inhibit fishing, swimming, boating and removal of irrigation water.

3. They can cause oxygen depletions if they die suddenly; fish kills may result as the vegetation decomposes, especially during extended periods of hot, cloudy weather.

4. Certain species can emit offensive odors and give the water a bad taste.

5. Certain blue-green algae produce poisons that can kill fish, birds and livestock.

6. Shallow water which is choked with vegetation provides ideal spawning areas for mosquitoes and habitat for predaceous arthropods, such as dragonfly larvae and back swimmers.

7. They utilize the pond's fertility.

The following key to identifying aquatic plants and illustrations of these plants were developed by E. Ray Smith, regional biologist for SCS in Fort Worth, when he was a biologist for SCS in Louisiana. They are part of the SCS publication <u>Land Management Guide - A Supplement to Biology Standard and Specifications for Louisiana</u>.

This key can be used with a high degree of success for aquatic plants in the wild, but it does not include all of the aquatic species. If the key does not work out to your satisfaction, refer to the field office references on aquatic plants or send a specimen to the state office for identification.

A key is a series of choices. Plants with similar characteristics are grouped and these groups are presented as alternates in the key. For example, you find a woody plant growing along the edge of a farm pond and turn to the key for aid. The first choice you have is shrubs, trees, or herbs. Since the stem is woody, this eliminates herbs, so you go to Group A. Under Group A you have two choices, leaves opposite or leaves alternate. Since the leaves are alternate, you move on to number 2. Here again two choices are available. The plant you found has narrow and elliptical leaves, so it is a willow.

Under some conditions there may be a series of choices, 3 to 5 alternates, because so many plants fall under one large group.

Be careful, read all the choices, gather as much of the plant as possible, and be sure that you have all the different kinds of the plants in a pond with weed problems.

KEY TO AQUATIC PLANTS

I. Shrubs or Trees - Group A

I Herbs - II

II Plants, free floating - Group B

II Plants attached to bottom - III (Free floating masses of the plant in question may be present that have broken loose from the bottom. Check to see if attached vegetation is present.)

III Stems limp and floating, submerged or on the surface - Group C

III Stems erect and emergent, rooted - Group D

Group A

1. Leaves opposite or whorled in 3's - fruiting head round - Buttonbush

1. Leaves alternate - 2

   2. Leaves narrow and elliptical, bark rough - Willows

   2. Leaves egg-shaped, bark relatively smooth and gray, trunk fluted- Alders.

Group B

1. Very small, green or red plants about 1/16 to 3/8 inch long. Rootlets may be present dangling in the water.

   a. Plants green (sometimes reddish), small 1/16 to 1/8 inch, oval nearly circular or in some cases crescent-shaped. May look like small green seeds floating on the water - Duckweeds.

   b. Plants red to brownish-red, larger than above, 1/4 to 1/2 inch long. Composed of a forked stalk with overlapping scales - Waterfern.

1. Plants very much larger and taller.

   a. Plants with large, deep green, glossy leaves which are circular to heart-shaped with inflated bases. One to many such leaves, large mass of roots floating in water. May attach themselves to mud in shallow water. Up to 2 feet tall and bearing beautiful purple flowers - Water Hyacinth.

   b. Plants not as above. Resembling an open head of lettuce. Leaves wrinkled, velvety and light green in color. Roots trailing in the water - Water lettuce.

c. Leaves roughly heart-shaped, long stalked from a central cluster. Leaf veins originating from the point of attachment to stem. Flower white. Fruit rounded and dropping at maturity - Frogbit.

Group C

1. Plants with surface leaves - 2

2. Leaves circular, oval, elliptical or heart-shaped - 4

4. Leaves Circular

a. Leaves small, less than 2 inches, with indented edges, one leaf per stalk. Stem attached at middle of leaf. Stem arises from a creeping rootstock - Pennywort.

b. Leaves larger, 4 to 10 inches in diameter, a single deep cleft. Flower large and showy, white to pink - Waterlily.

c. Leaves very large, erect or floating on the surface, up to 24 inches in diameter. Margins of leaves turned up on some. Flower large, yellow, erect on a separate stalk. Seed pod hemispherical with flat top and large seeds - Lotus.

4. Leaves Oval

a. Leaves 3/4 to 4 inches long, connected to the stem in the middle of underside. Underside and stem red, encased with a slimy covering. No underwater leaves. Flowers inconspicuously brick red - Watershield.

b. Leaves connected as above, but smaller - 3/4 inch or less, not red or slimy. Leaves small. Underwater leaves fan-shaped and divided - Fanwort.

c. Surface leaves of various sizes, generally small, 1/2 inch to 4 inches, and connected to stem at end of leaf. Underwater leaves narrow and grass-like, length variable. Seed head may be stalked and above the water or in clusters in axils of the leaves - Pondweeds.

4. Leaves Heart-Shaped

a. Leaves small, deeply cleft, 1 to 6 inches in diameter with irregular edges. Flowers white, several and stalked, with the stalk originating from the stem just below the leaf - Floating Heart.

b. Leaves large 7 to 16 inches. May be held upright or laying on the water. Flowers solitary, yellow, waxy and born on a separate, upright stalk above the water - Spatterdock, Cow lily, Yellow Waterlily.

4. Leaves Not As Above

a. Leaves elliptical and alternate. Above the leaf base is a sheath clasping the stem, the upper edge of which is fringed with long hairs. Nodes swollen. Flowers small, pink or white - Smartweed.

b. Leaves many, elliptical and opposite. Leaves and stems succulent forming floating mats on the water or standing upright in shallow water or damp soil. Flowers small, white cloverlike and on stalk standing above the water - Alligatorweed or Alligatorgrass.

c. Leaves elliptical. Upright stems are red and the sprawling, vinelike ones on the water are green. Occasionally stems turn up and have aerial leaves that have enlarged rounded tips. Flowers, yellow, are borne on aerial shoots - Waterprimrose.

d. Leaves opposite, with enlarged, rounded or pointed tips. Stems red all year but the whole plant turns red during the winter - False Loosestrife.

e. Leaves solitary, short and grasslike, and continuing as a sheath below the base of the blade. Stems limp and fine. This plant forms mats on the surface in shallow water, but sometimes extending into deeper water - Carolina Watergrass.

f. Leaves small, finely divided and bright green, or leaves elliptic in outline, noticeably serrate, dark green in color and appressed to the stem. Stem brittle and having wheel-like pith. Underwater leaves larger and finely divided - Parrotsfeather or Watermilfoil.

1. Plants Without Surface Leaves - 3

3. Plants having stems and undivided leaves or just undivided leaves--1.

1. Plants with simple undivided leaves - 2

2. Leaves whorled on stems

a. Stems and leaves medium to dark green, brittle, have a gritty feeling when handled. Leaves

round and curved upward. Have a pungent odor when crushed. Small black "seeds" may be present - Chara.*

b. Leaves whorled, flat, short grass-like, light to dark green and translucent. Flower small, pale yellow, 3 petals - Waterweed.

c. Leaves generally whorled but may appear alternate. Blades grasslike, flat and pointed. Plants coming from a continuous black runner - Juncus repens.

2. Leaves Opposite

a. Leaves narrow and grass-like, short and pointed. Plants from green to brown. Generally grows in dense beds. Seed spindle-shaped, borne in axils of the leaves - Najas.

b. Leaves pale to bright green with enlarged, rounded tips. Generally it does not grow in dense beds - Waterstarwort.

2. Leaves Alternate

a. Leaves flat and grass-like, may be whorled or alternate. Plants arising from a continuous black runner - Juncus repens.

b. Stems round, leaves flat, narrow and of varying length, grasslike. Seed flattened laterally, but rounded in sideview, found in clusters below or stalked above the water - Pondweed.

c. Stems and leaves wirey and round, branching into a tangled mass, dark green. May be attached or free floating in mats - Proliferating Spikerush.

1. Leaves Divided Once or More

a. Leaves whorled and forked once or more at the tip and have a spiny appearance - Coontail*

b. Leaves fan-shaped and finely divided, may be whorled or opposite - Fanwort.

*Use extreme care with this plant as it sometimes closely resembles Coontail. Check the accompanying drawing at the close of this key.

c. Leaves finely divided, may be whorled or alternate, grayish-green to bright green in color. Translucent green or black "seed-like" units sometimes present. Flowers are stalked and above water, three petals, yellow or purple. A highly variable plant - Bladderwort.

d. Leaves finely divided, brownish or green in color, stems red or green, hollow, brittle, with a fine central wheel-like pith. Aerial leaves may be present - Watermilfoil or Parrotsfeather.

Group D

1. Leaves grass-like-round, flat or V-shaped, especially near the base 2.

   2. Leaves flat in cross section.

      a. Leaves sword-shaped, narrowly elliptical in cross section. Seed head long, cylindrical, and brown at maturity - Cattail.

      b. Leaves long, up to 6 feet, grasslike with sharp cutting edges, seed head lax and drooping. Plant grows in large clumps and may turn tan or white in the winter - Giant cutgrass.

      c. Leaves grasslike but V-shaped in cross-section, especially at the base. Leaves 3 ranked and continuing as a sheath on the stem. Stems 3-sided, sometimes rounded on edges, pith filled without nodes. Seed heads of various types but usually prickly in appearance - Sedges.

   2. Leaves Round in Cross Section

      a. Leaves dark green with pointed tips. Fruit borne in a dangling cluster from the side, below the tip - Rushes.

      b. Leaves medium to light green, short, 1 to 18 inches (stems square in cross-section in one taller species). Seed head borne on tip of stems - Spikerush.

1. Leaves not grass-like, various shaped - 3

   3. Leaves of Various Shapes - 1

      1. Leaves Elliptical

a. At the leaf base is a clasping sheath enclosing stem, with long hairs protruding from the upper edge. Flowers, pink, green or white, small. Joints swollen - Smartweed.

b. Leaves may be as above or with enlarged rounded tips, growing upright on land, sprawling or "viney" on the water. Flowers yellow and one inch or more in diameter - Waterprimrose.

c. Leaves opposite, plants succulent, growing upright on land and forming mats in deeper water, flowers small, white and clover-like - Alligatorweed or Alligatorgrass.

d. Leaves elliptical, alternate, with 2 sharp, long thin spines (about 1/2 to 1 inch) at the base. Growing in damp soil to shallow water. Flowers blue to purple emerging from the leaf bases. Stems weak. Note: Spine may be absent in young plants - Waterleaf.

e. Leaves narrow and elliptical, only one per stalk. Stalk triangular in cross-section. Flower stalk straight or branched, bearing a few to many small, white 3-petal flowers - Bulltongue.

1. Leaves shaped like an Arrowhead

a. Tips of the lower leaf lobes rounded, flower blue or purple - Pickerelweed.

b. Tips of the Lower Leaf Pointed

1. Lateral vein horizontally separating the leaf about in middle. This may not be distinct. Flowers small, many, and white, flowering stalk branched - Arrowhead.

2. Lateral vein paralleling lower leaf lobe edge. Very noticable on back of leaf. Outer stems sheathing, inner ones like celery. Flowers yellowish or green, encased in a sheath - Arrow-arum.

1. Leaves Heart-Shaped

a. Leaves stalked, roughly heart-shaped, arising from a central cluster. Veins of leaves originating from the point of attachment. Flowers white. Fruit rounded and drooping at maturity - Frogbit.

b. Leaves heart-shaped, large, 7 to 16 inches, and a single leaf per stalk. Flowers 1 to 1-1/2 inches in diameter, yellow and waxy - Spatter-dock.

c. Many small heart-shaped leaves present. White flowers in a terminal, cylindrical cluster, often nodding and forming a "question mark" - Lizardstail.

1. Leaves Round

a. Leaves round with indented margins, small, 1 to 2 inches in diameter - Pennywort.

b. Leaves very large, up to 24 inches in diameter standing upright above the water. Flowers stalked above the water, large and yellow - Lotus.

1. Leaves Opposite

a. The opposite leaves are enlarged and rounded or pointed at the tip, plant turns red in the winter - False Loosestrife.

1. Leaves Whorled

a. Leaves finely divided, bright parrot green in color. Underwater leaves usually present; they are more finely divided than aerial leaves, larger, and brown in color. Stem brittle and green to brown in color and has a central wheel-like pith - Parrotsfeather.

b. Leaves prickly looking, elliptical, short, growing upright or leaning toward the main stem. Underwater leaves and stem as above - Watermilfoil.

GLOSSARY TO PLANT KEY

Divided leaves - leaves which are divided into narrow subsections, which in turn are subdivided into smaller subsections. This subdivision may take place three or four times, or only once or twice.

Leaves alternate - leaves that are alternately placed (one on the left, the next on the right, etc.) along the stem. They are never directly across from one another except when crowded towards the tip of the plant.

Leaves opposite - leaves borne directly across from one another along the stem.

Leaves whorled - leaves, three or more, that are placed in a circle around the stem, all at the same level.

Leaf lobes - the lower portion of a leaf which protrudes below the point of petiole attachment.

Nodes - swollen points along the stem of a plant where leaves are or have been attached.

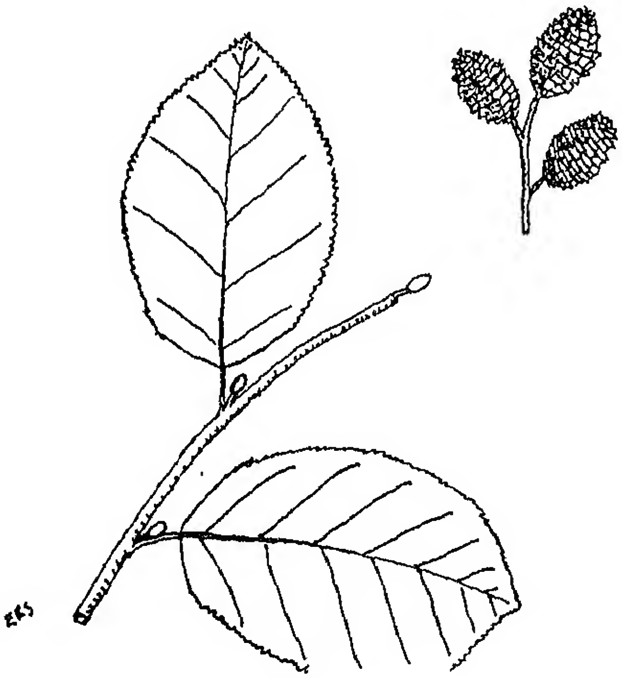
Leaf sheath - a continuation of the leaf blade which is completely or almost completely wrapped around the stem above the point of attachment.

Three-ranked leaves - leaves which are grown on a triangular stem and appear on these stems in an alternate placement.

Wheel-like pith - wheel-like pith resembles a spoked wheel, with the hub at the center and spokes of pith radiating out from this to the outer edge.

LIST OF PLANTS ILLUSTRATED

FIGURE 9



Buttonbush (Cephalanthus) - Upper Left

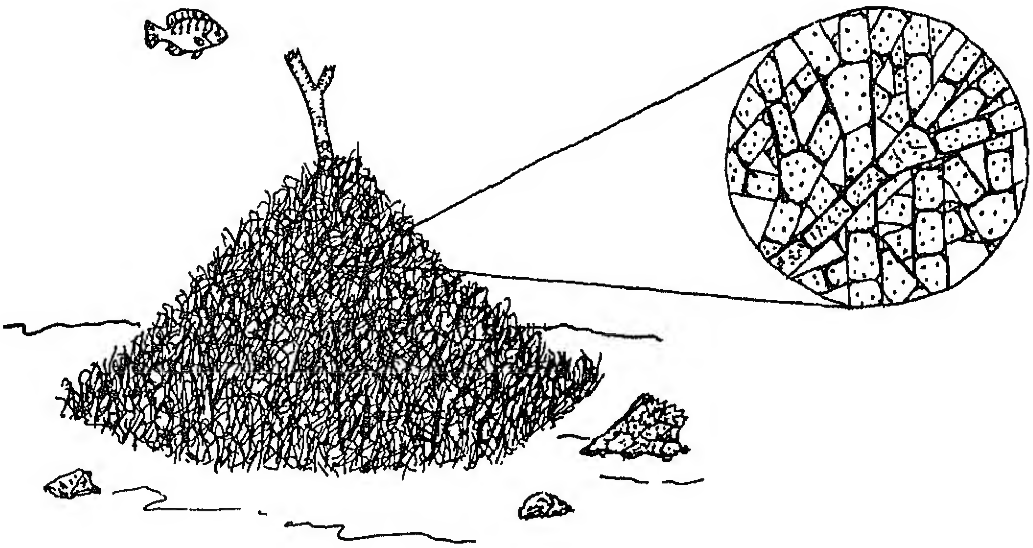
A bushy,woody perennial that grows to the height of 6-7 feet or higher, in wet areas. The oval leaves are opposite or sometimes whorled in 3's or 4's. The fruit is round and slightly resembles sycamore "balls". The fruit disintegrates upon maturity into individual "wedge shaped" seeds.

Willow (Salix) - Upper Right

A low growing tree found in various wet to damp situations. The leaves are lance-shaped and borne alternately on the twigs. The fruit is a very small seed with long silky hairs. Frequently windrows of this seed under the tree make the ground look as if it were covered with down.

Alder (Alnus) - Lower Left

A woody shrub that will grow 10-15 feet or higher. The alternate leaves are roughly egg-shaped with a fine saw-tooth margin. The bark is smooth and gray and the trunk is generally grooved with rounded ridges. The seeds are borne is a small "cone", resembling a miniature pine cone.



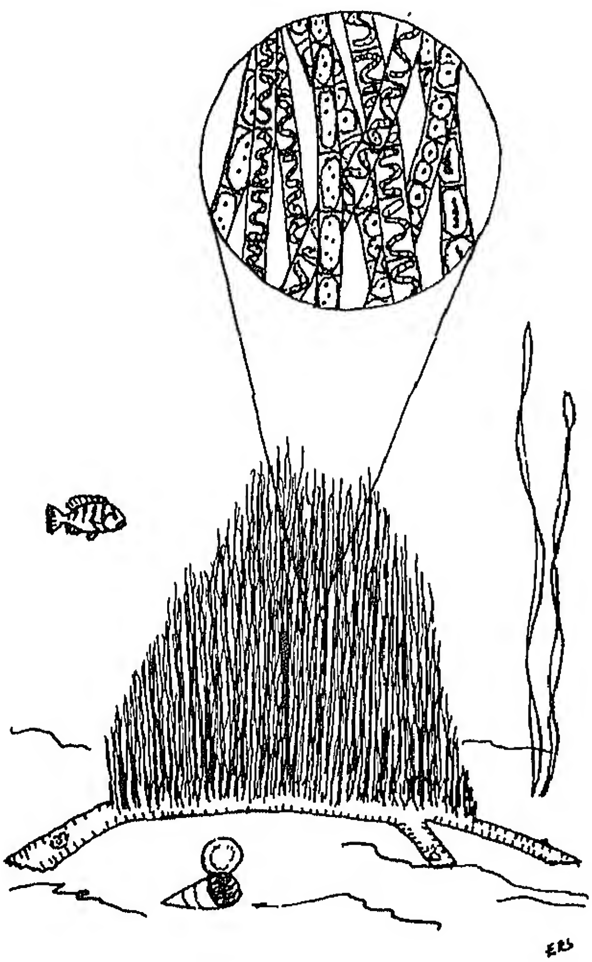
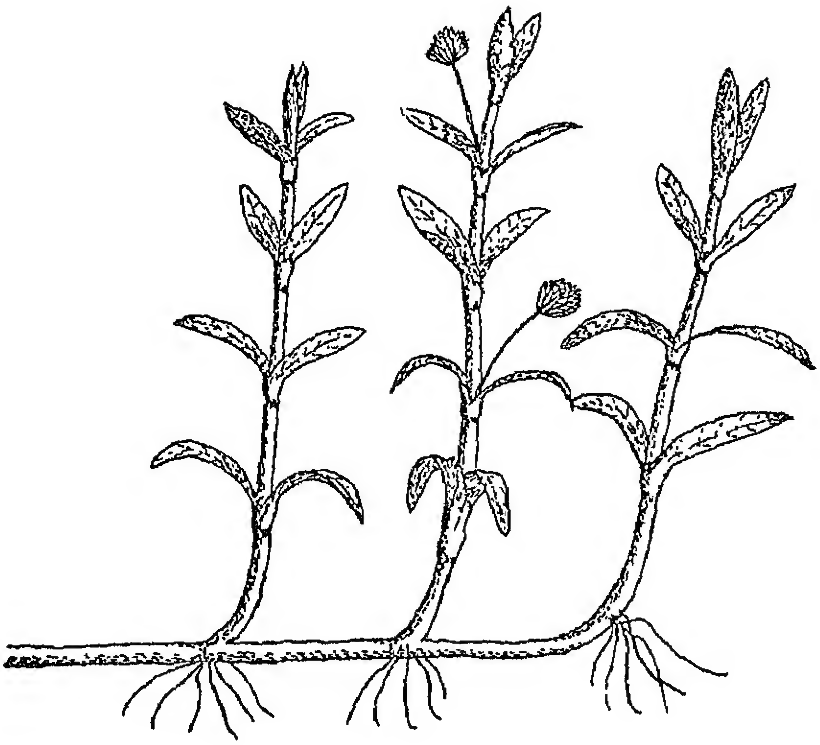


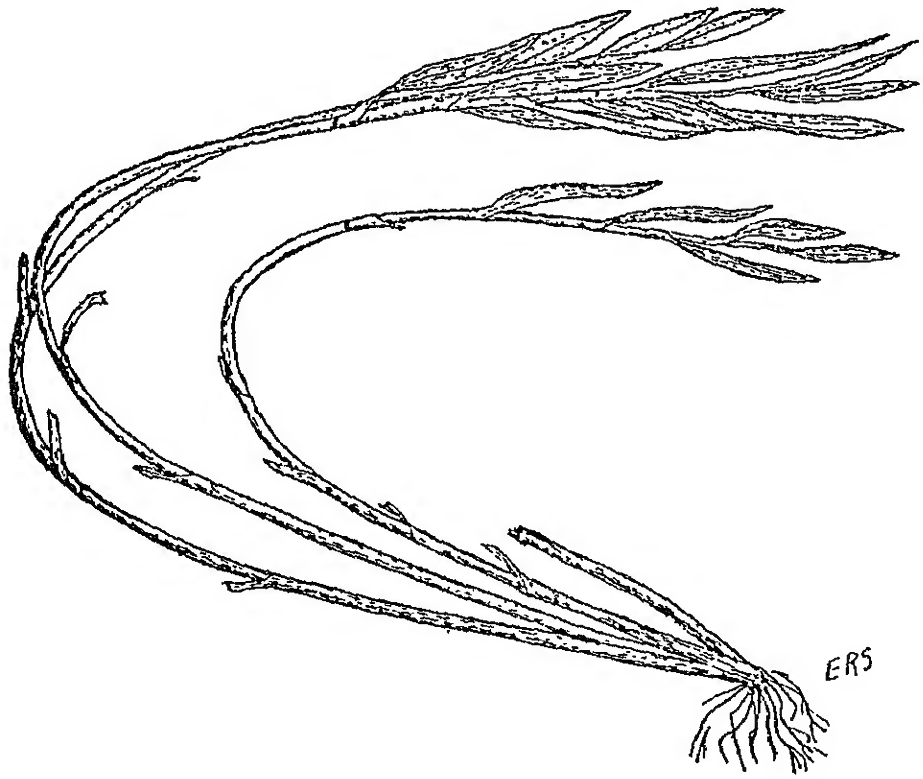
FIGURE 10

Algae, Pond Scum (Various Species) Growing on the bottom or on and around objects. Later coming to the surface in large mats whereupon it dies and decays. Two forms are present, the branched form (upper) and the single filamentous (lower). The branched form is green to grayish-green and coarse feeling like wet cotton. The single filament is slimy to the touch and green to brown in color.

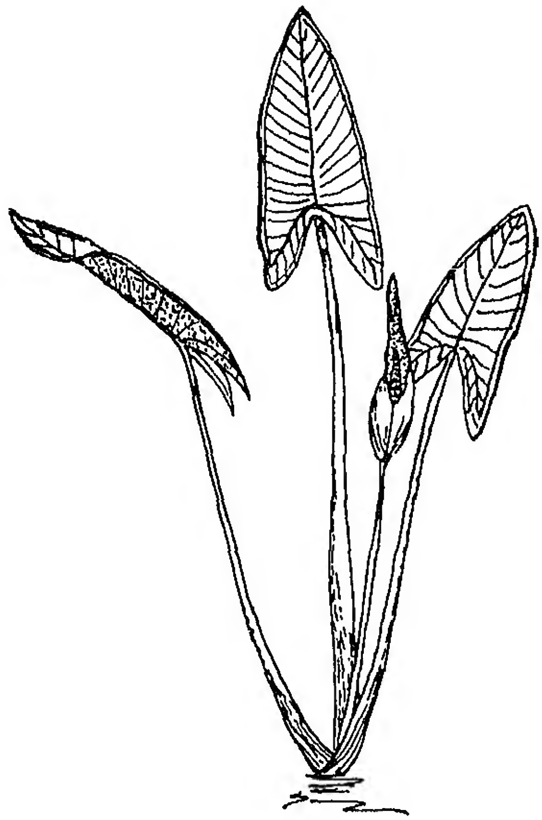
FIGURE 11



Alligatorweed (Alternanthera) May be found growing upright on damp soil or growing as a floating mat in water. Leaves roughly oval and opposite one another on the stem. The bases of the leaves merge to form a sheath which is slightly swollen. Leaves and stems succulent and fleshy. Flowers white and resemble the flowers of white clover. These are borne on a long stalk growing between the stem and leaf. Seeds are not viable and this plant reproduces vegetatively from the nodes.



Carolina watergrass (Hydrochloa)- leaves small, (1-2 in long x 1/4 in. wide) ellipical grayish green to green in color. These are found mainly towards the end of the stem and float on the surface. This plant can be found growing next to the shore or in shallow water. May form floating mats which can cover up small ponds. Rarely fruits.



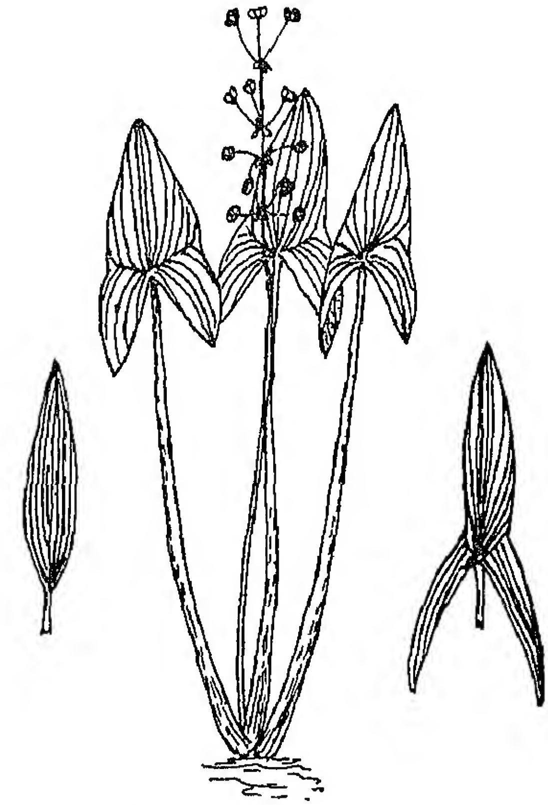
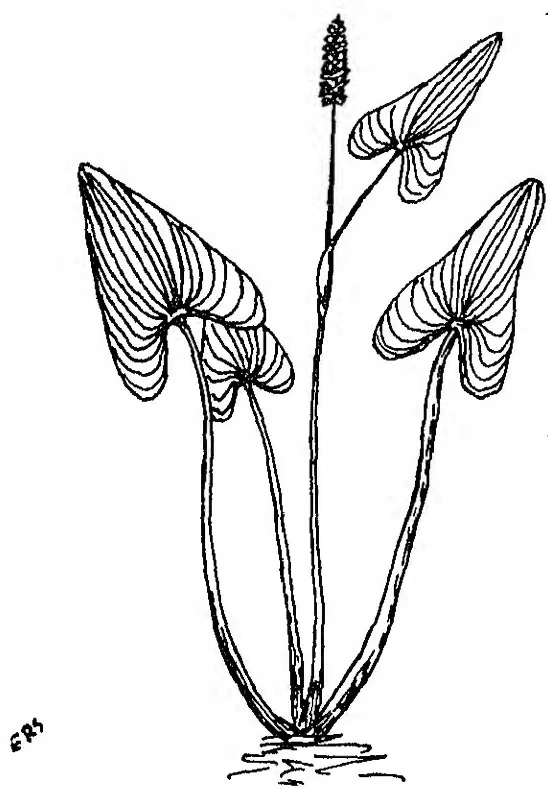


FIGURE 12



Arrow-arum (Peltandra) - Upper Left

The leaves are shaped like a barbed arrowhead and are borne on thick "fleshy" stems. The yellow "flowers" are enclosed in a green, partly opened, sac-like structure which terminates in a wrinkled tip. The skin of the fruit is green, purplish or brown and the seeds are enclosed in a gelatinous mass within the fruit.

Arrowhead (Sagittaria) - Upper Right

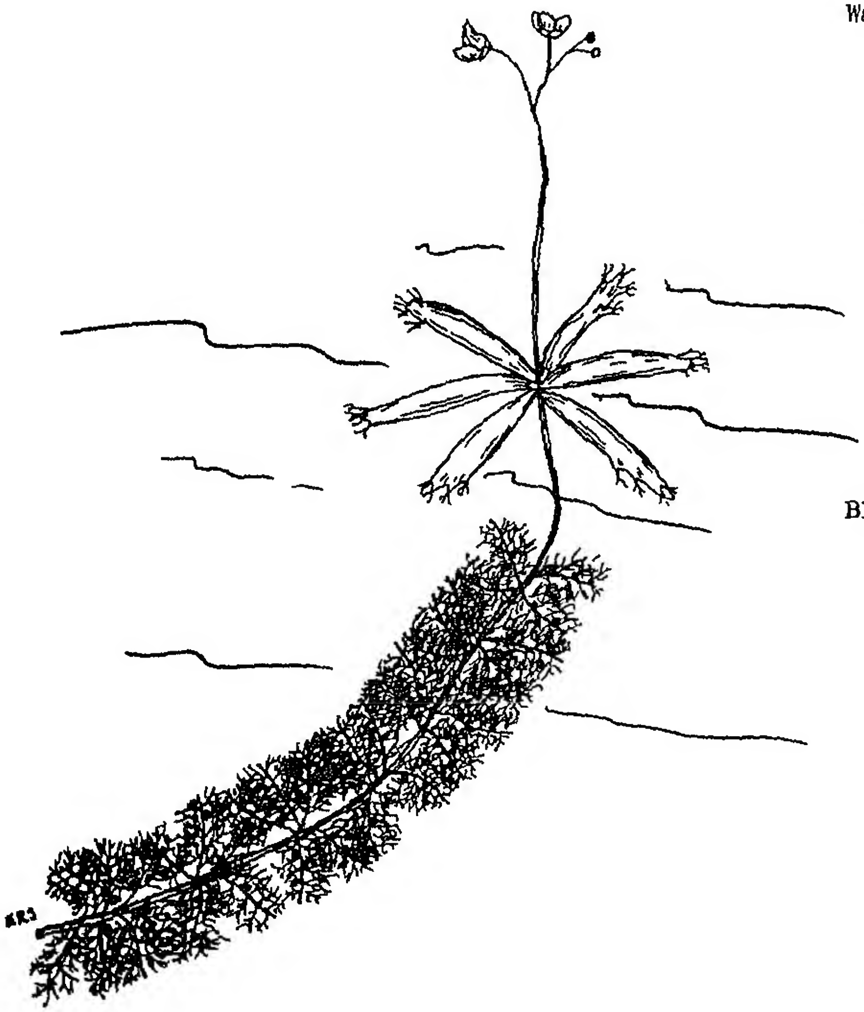
The leaves are highly variable, but are generally arrowhead shaped, though the "barbs" may or may not be present, according to the species and water depth. The small white flowers are in whorls of three along the main stalk.

Pickerelweed (Pontederia) - Lower Left

The leaves are heart-shaped and are borne on thick stems. The flowers are bluish and found in a terminal spike.

Note: In the case where the flowers are absent, these plants may be differentiated by the veination of the leaves. See the illustrations.

FIGURE 13



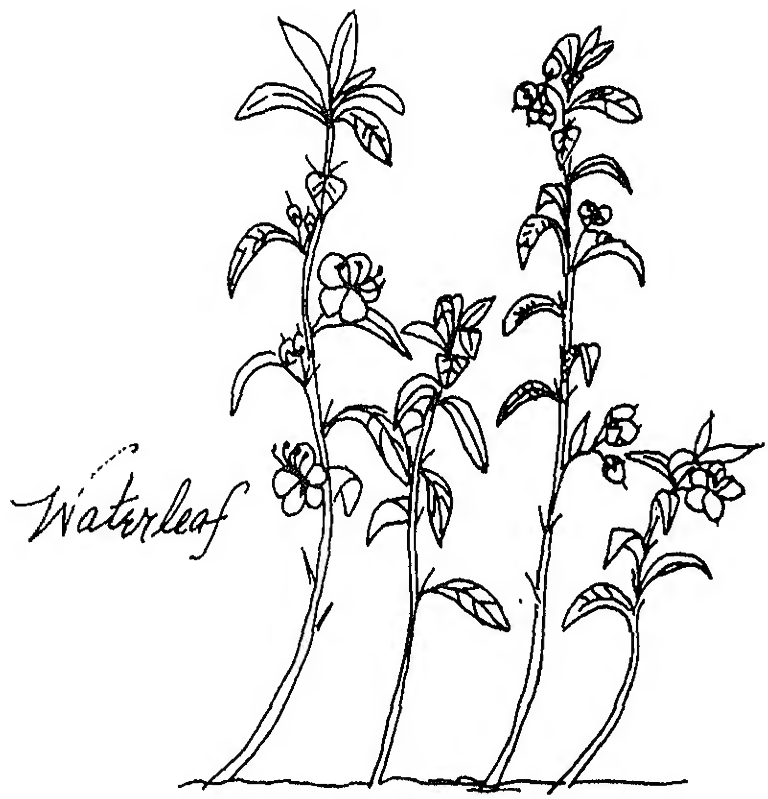
Water Primrose (Jussiaea) - Upper

A creeping plant found in the margins of ponds or lakes. The flowering stalks turn up and grow out of the water. The leaves along the prostrate stems are narrowly elliptical while those of the flowering section have much more rounded and broader tips. The flowers are large (about 1 inch across) and are varying shades of yellow. Frequently these plants will put out white "foamy" looking aquatic roots that lie near the surface.

Bladderwort (Utricularia) - Lower Left

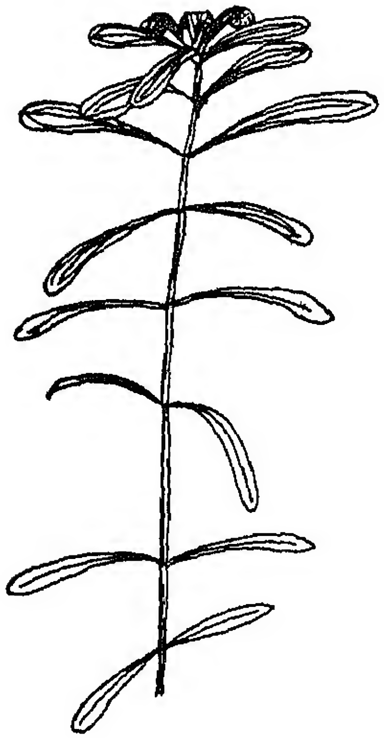
This plant is generally free-floating, but occasionally rooted. The mainstem is thin and the leaves are irregularly spaced along it. The leaves are much divided and thread-like. Small black bladders are borne among the leaves and are distinctive enough for identification. The flowers are borne above the water and sometimes have floats at their base, depending on the species. The flowers are yellow or purple. Generally found in acid waters.

FIGURE 14



Waterleaf, Hydrolea - The only emergent aquatic plant with spines. These are found growing at the base of the leaves and generally there are two present. Leaves ellipical to oval and alternately spaced on the stem. Flower blue and seed pods round. Found growing in damp soil to shallow water.

Bulltongue, Sagittaria - stems clasping and thickset at the base: triangular in cross section leaves very narrowly to broadly lance shaped. Flowers small, white and 3 petaled. Three flowers to the whorl. Seed heads small and yellowish. This plant is in the same family as arrowhead but the leaves never have the arrowhead shape.



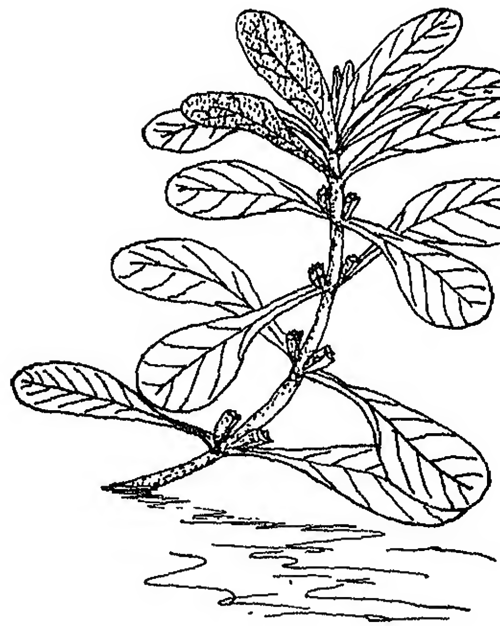


FIGURE 15

Water Starwort (Callitriche) - Upper Left
Small, aquatic perennials with slender stems growing in shallow water. The leaves are opposite, the lower submerged ones being narrowly cigar-shaped, while the upper floating leaves have widened tips. When looking down on the floating leaves, they roughly form a star-shaped pattern.

False Loosestrife (Ludvigia) - Upper Right
Low, marginal, succulent plants with opposite "spoon shaped" leaves. These plants usually are creeping or floating. The reddish stem and green leaves are distinctive. In the winter months the leaves may be red to purple.

Bur Reed (Sparganium) - Lower Left
A perennial aquatic plant growing in shallow water to damp sites. Prefers acid water. The leaves are grasslike, but more succulent and partly folded near the base. The seed heads, composed of elongated top-shaped seeds, are very distinctive in appearance and should serve to identify this plant.

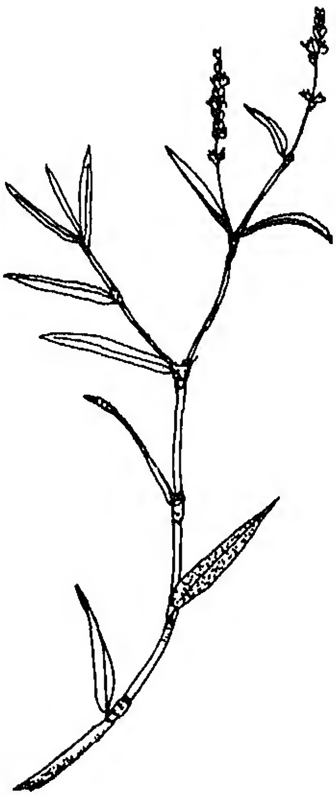
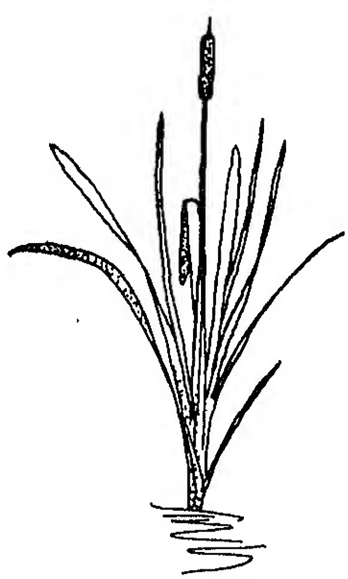


FIGURE 16



Smartweeds, Water Pepper (<u>Polygonum</u>)

Plants inhabiting the shallow water of a pond, with lance-shaped, alternate leaves. At the base of each leaf is a sheath going around the stem and topped with long, fine hairs. The flowers are pink, white, or greenish and found in terminal spikes or on short lateral spikes originating between the leaf and the stem. The seed is either triangular or lens-shaped in cross-section. These seeds are a choice food for ducks.

Lizardstail (<u>Saururus</u>)

Succulent herbs, with jointed stems and alternate drooping heart-shaped leaves, found along the edges of the water. The long, nodding, white flowered spike is present during the summer and easily distinguishes this plant.

Cattail (<u>Lypha</u>)

Long, narrow, veinless, bluish-green leaves, sheathing at the base of the plant and the familiar seed head are enough to identify this plant.

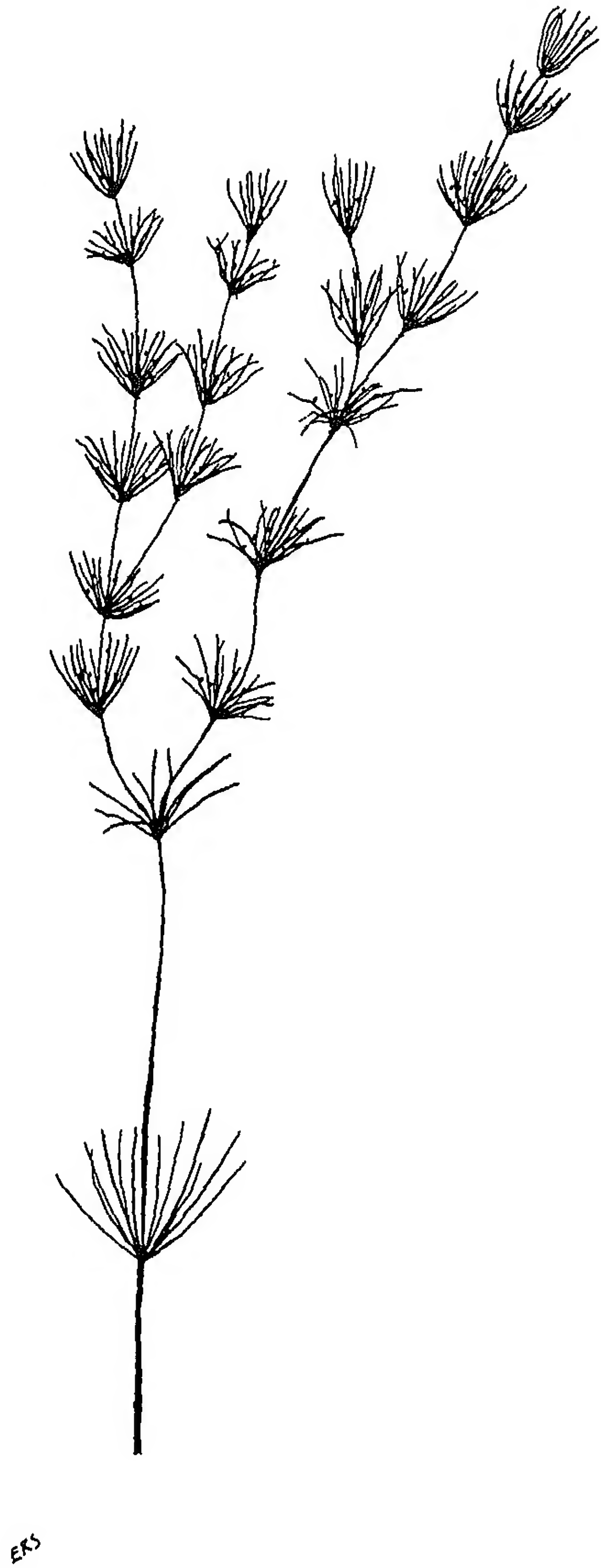
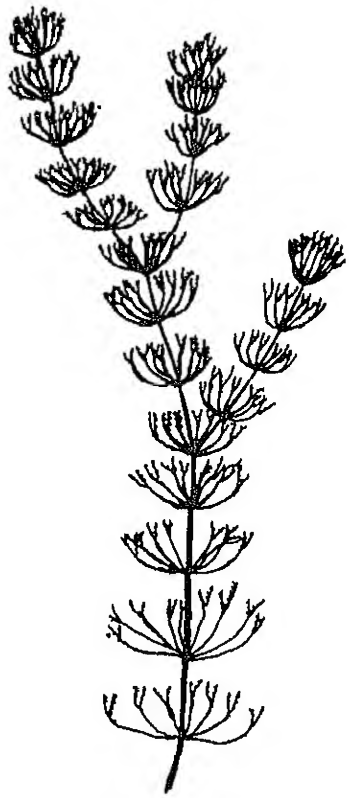
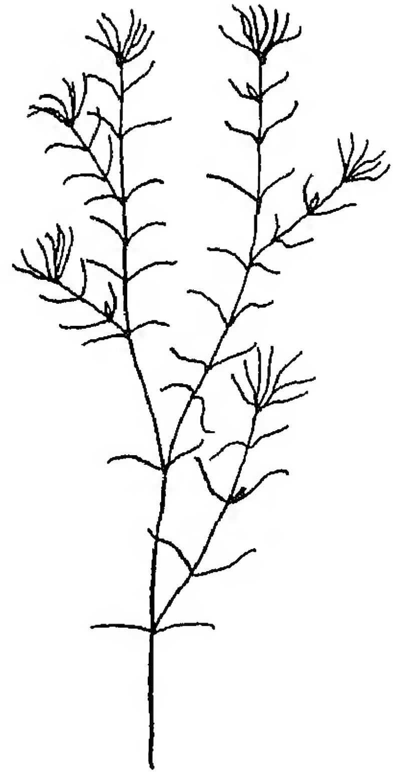


FIGURE 17

Stoneworts - Muskgrass (Chara)
Actually a higher form of perennial algae. The 6-12 leaves are cylindrical and arranged in whorls around the stems and branches. Stems, branches, and leaves are very brittle, and when crushed, emit a strong musk-like, or "skunky" odor. The "fruit" or oogonium appears as small black dots scattered over the leaves of the plant. Variable in height but generally not reaching the surface of the water. All parts of the plant are eaten by waterfowl.





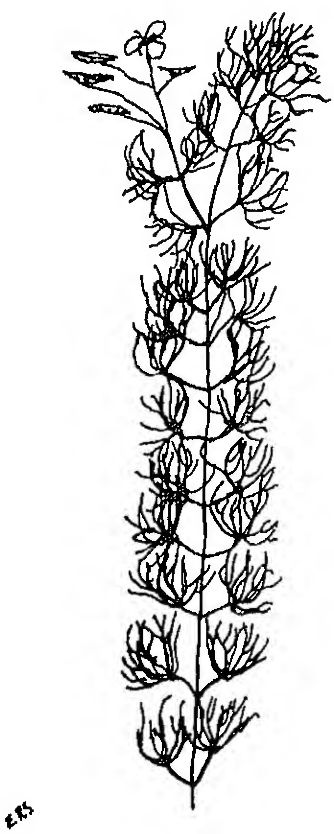


FIGURE 18

Coontail (<u>Ceratophyllum</u>) - Upper Left

A submerged brittle herb, with leaves in whorls about the main stem, which is generally forked once to several times. The leaves are very fine and forked (sometimes divided into 3's) at the tips. These "tiplets" have a "spiny" appearance because of their wavy margins. This plant is "rooted" in the spring and early summer and free-floating in the late summer and early fall. The seeds of this plant are taken by water fowl.

Naiads (<u>Najas</u>) - Upper Right

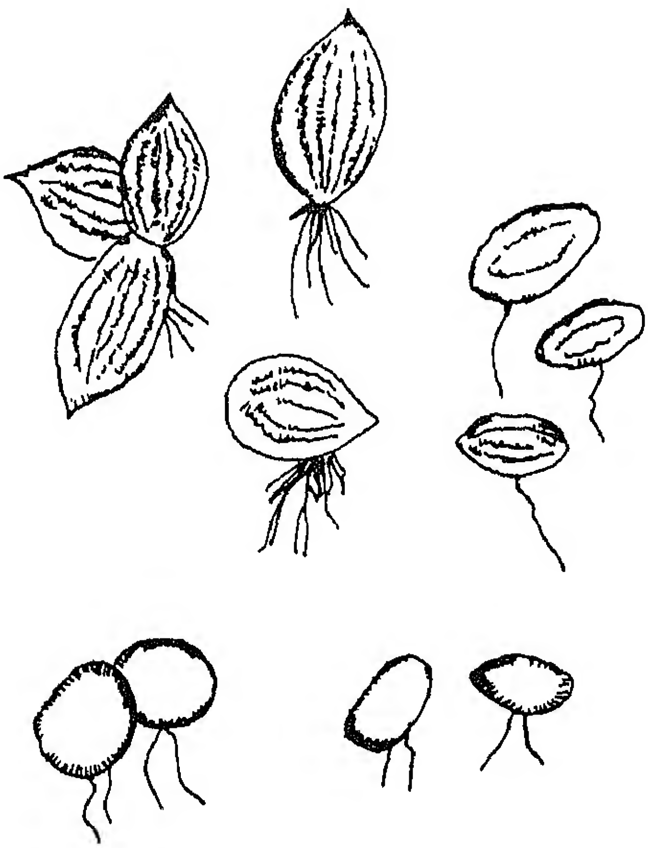
Submerged herbs with opposite or whorled, narrow to threadlike leaves. The bases of the leaves sheath the stem. The mainstem is branched and has fibrous roots. The seeds are small and elliptical and are found in the axil of the leaves. This plant is a favored food of many ducks.

Fanwort (<u>Cabomba</u>) - Lower Left

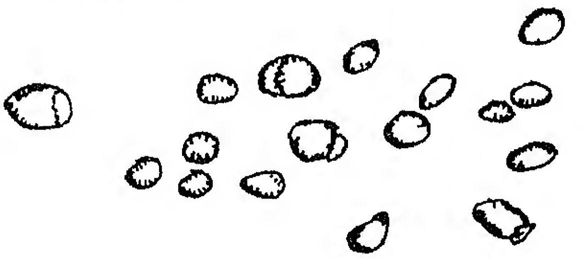
Delicate, branched, submerged herbs with finely divided leaves that are opposite or in whorls. Occasionally the upper floating leaves are produced. These are small, oblong, and attached at the center of the blade. The flowers are small and have three white to yellow petals.

FIGURE 19

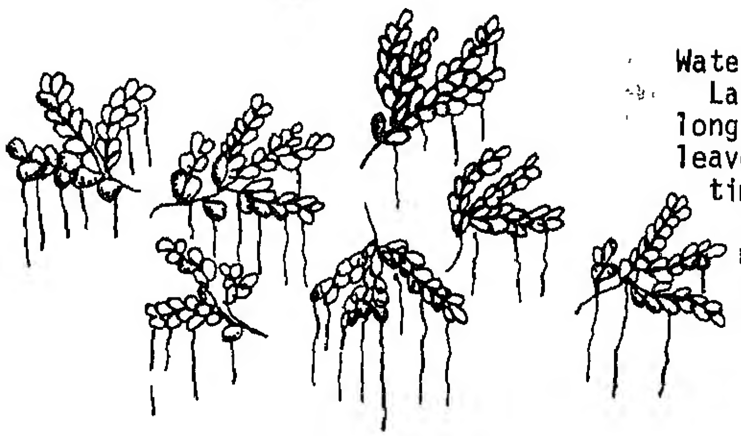
FREE FLOATING PLANTS



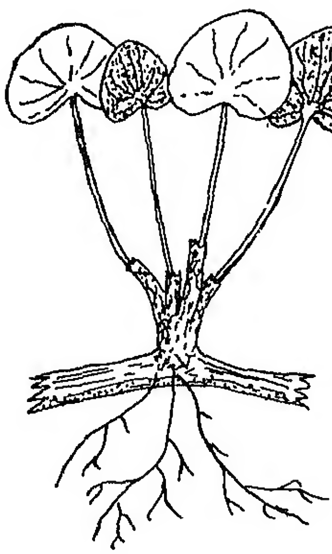
Duckweeds, Lemna and Spirodela spp.
Small, 1-12 mm long, free floating green plants of various shapes, generally oblong, that have one to many small rootlets hanging in the water, 1 to 15 nerves appearing on the top of the plants. Spirodela is larger and may be purple on the underside. These plants are 1-8 mm long, oval in outline with a small pointed tip, have many rootlets, and have 5-11 nerves on the upperside. Lemna has 1-5 nerves, one rootlet, green on the underside and smaller, being 1-5 mm. Under some conditions these plants may have a reddish color. It would be best to check them to prevent confusion with water fern.

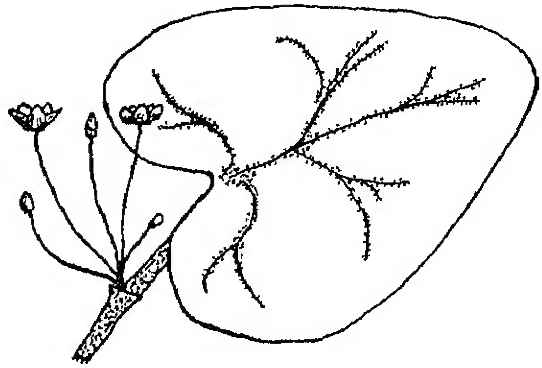


Duckmeal, Wolffia and Wolfella spp.
The tiniest flowering plant in the world, .5-2mm long, rootless, globullar to ellipsoid in outline.



Waterfern, Azolla sp.
Larger than the above, .5-1 cm long, having small overlapping leaves borne on a once to serveral times forking stem. Several small roots hanging in the water. At maturity these plants are red, rosey pink, or reddish brown. Young plants are green in color.





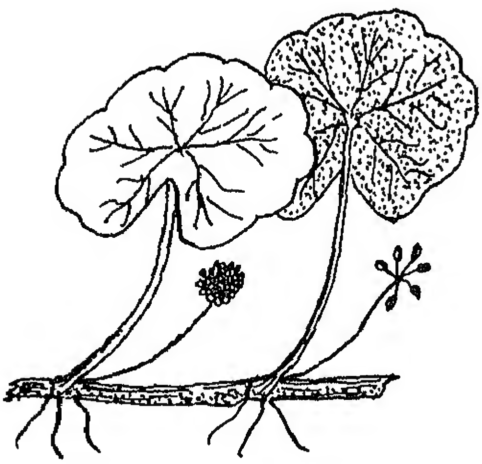


FIGURE 20

Mud Plantain (Heteranthera)-Upper Left

Leaves are in a flattened heart shape, stemming from creeping rootstocks. Usually growing in shallow water.

Floating Heart (Nymphoides)

Leaves small, 2-3 inches in diameter and roughly heart-shaped. Margins may be smooth or irregular in outline. The small white flowers are attached to the stem bearing the leaves just below the leaf. Occasionally a group of fleshy root-like structures are found on the leaf stem where the flower stalks arise.

Pennywort (Hydrocotyle) - Lower Left

Low, creeping plants with roughly circular leaves, the margins of which are wavy or indented. Leaves usually standing erect, but sometimes found floating. Flowers are borne in a small, round cluster. The fruit are roundish and ribbed vertically.

FIGURE 21

Frogbit Limnobium

Frogbit Limnobium - found in shallow water or rooted in the mud. When rooted the leaves appear as those on the left without the deeply indented heartshaped base. Flowers are small, white and star shaped. Roots may be found sprouting from the underside of the leaves when they come in contact with the water.

Giant-cutgrass

Giant-cutgrass - a very robust grass growing in clumps up to 6 ft. tall or taller. Leaves long and bearing spines or margins that can cut readily. Flower from February to August with the seed head a yellow-green in color and many times drooping. Grows from wet soil to shallow water.

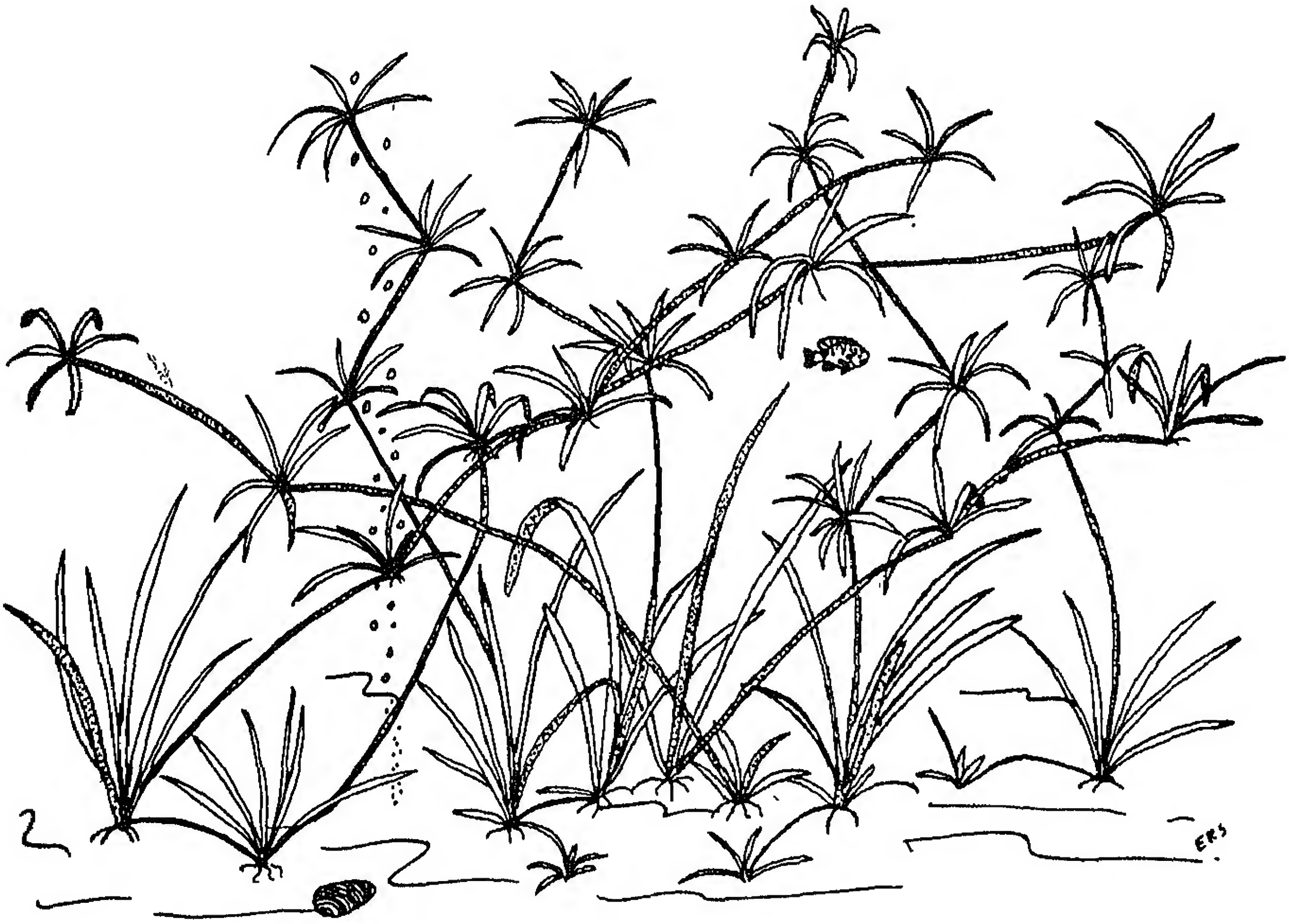


FIGURE 22

Juncus repens

Leaves - A member of the rush family but with grasslike, short and recurving leaves, growing in tufts along the proliferating stems or runners. Light green in color.

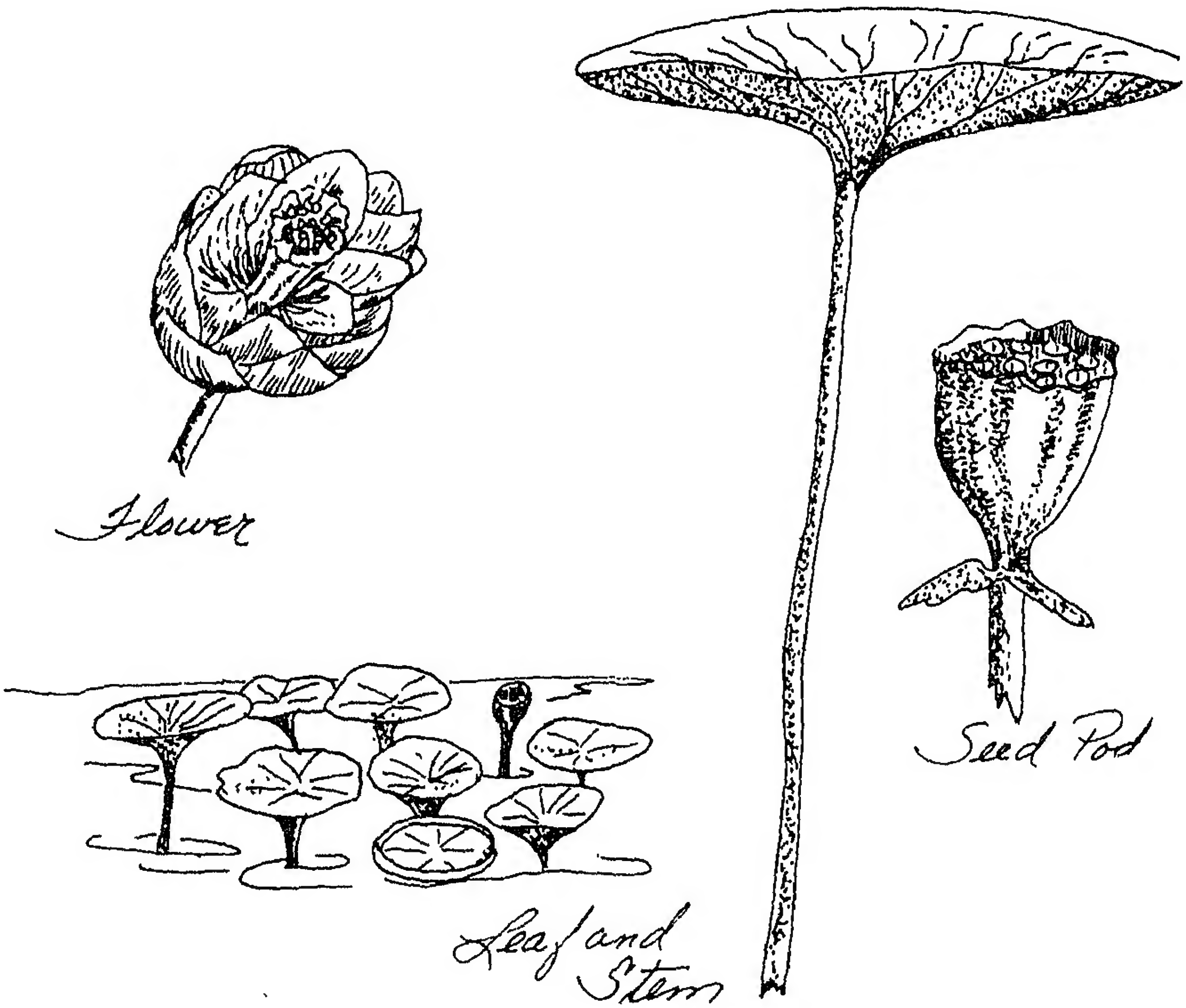
Stems - Lax and creeping. Producing a new tuft of leaves (or plants) as it grows. Appear as a flat, black runner.

Flowers - Not usually encountered, but when they are, they are at or near the tips of upright stems. Rusty brown in color and elliptical in shape, they are found in dense heads.

Special Characteristics - When seen from above, this plant looks like a grass submerged.

Habitat - Shallow water.

FIGURE 23



Lotus

<u>leaves</u> circular 12-24" in diameter, with the centers "cupped". Usually they stand up out of the water, but immature leaves lay flat on the surface.

<u>stem</u> 1/4 to 1/2 " in diameter, stiff and upright.

<u>flowers</u> 4.5 to 10" in diameter, pale yellow in color.

<u>special characteristics</u> The large, cupped leaves which stand upright are distinctive and characteristic of no other native plant.

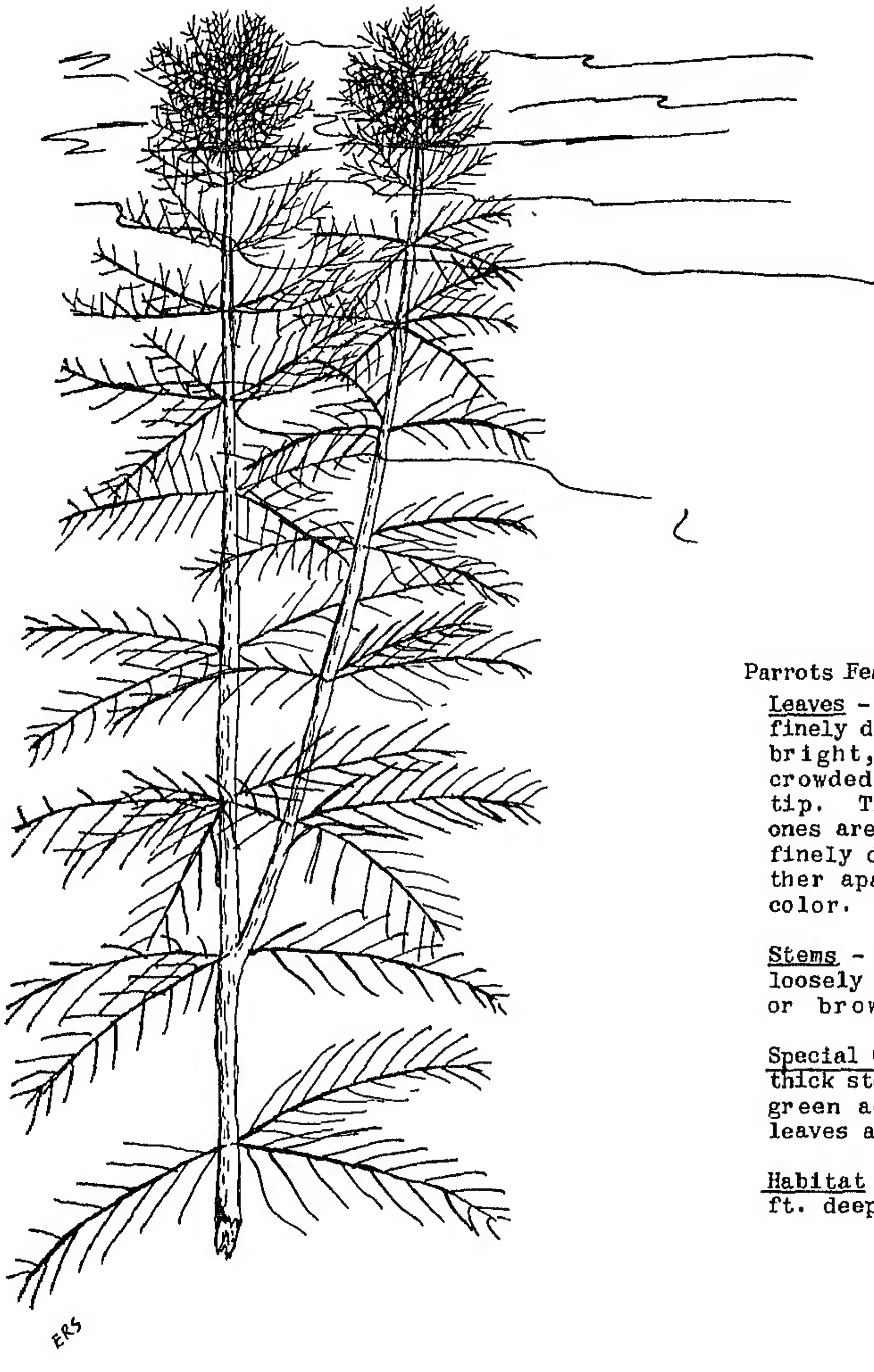


FIGURE 24

Parrots Feather (<u>Myriophyllum</u>)

<u>Leaves</u> - Upper ones are short, finely divided, feather-like, bright, light green, and crowded together near the tip. The lower submerged ones are much longer, not as finely divided, spaced further apart and brownish in color.

<u>Stems</u> - Thick and hollow or loosely pith filled, reddish or brown in color.

<u>Special Characteristics</u> - The thick stems and bright, light green aerial feather-like leaves are very distinctive.

<u>Habitat</u> - Shallow water 0-5 ft. deep.

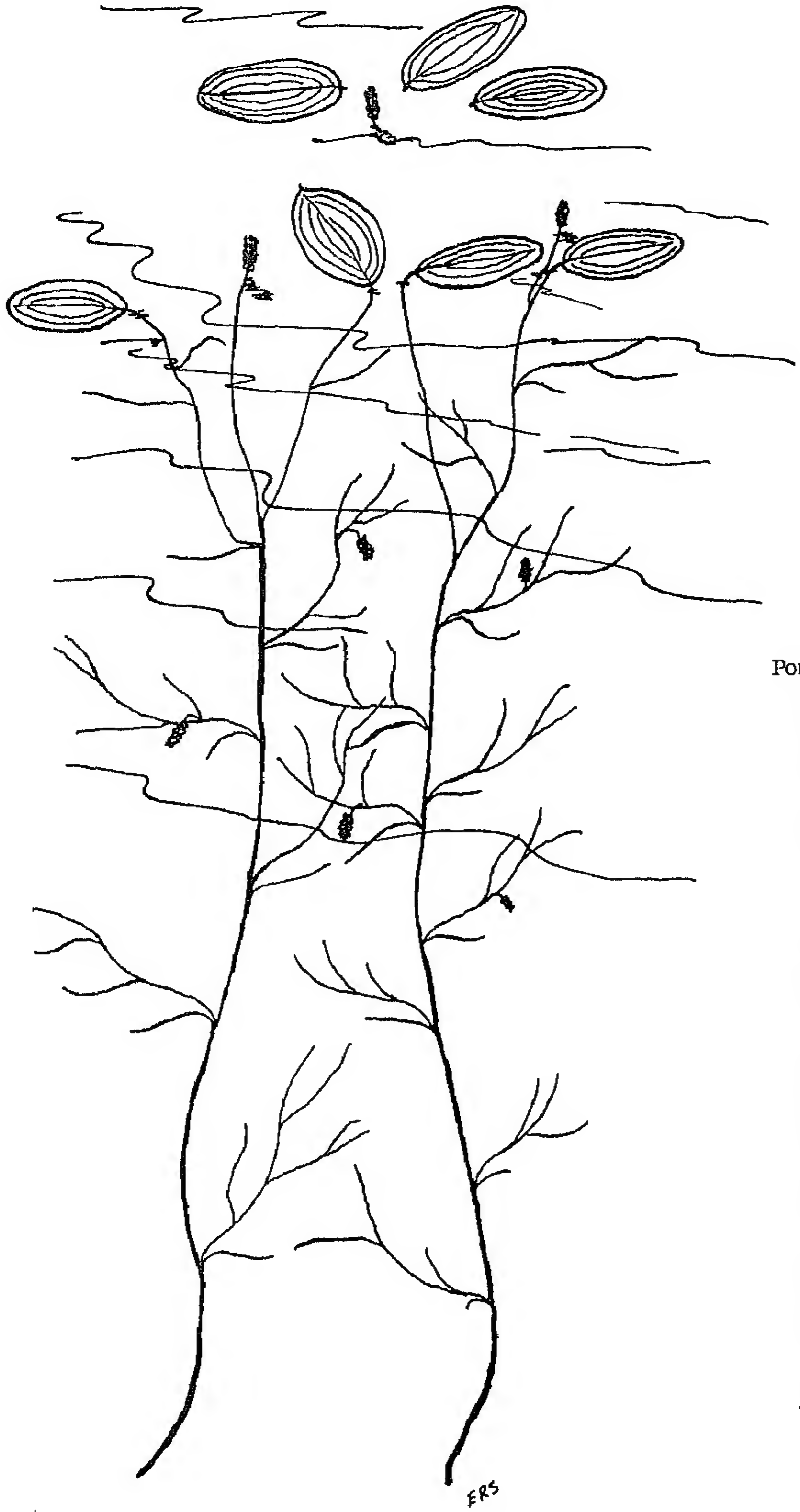


FIGURE 25

Pond Weeds (Potamogeton)

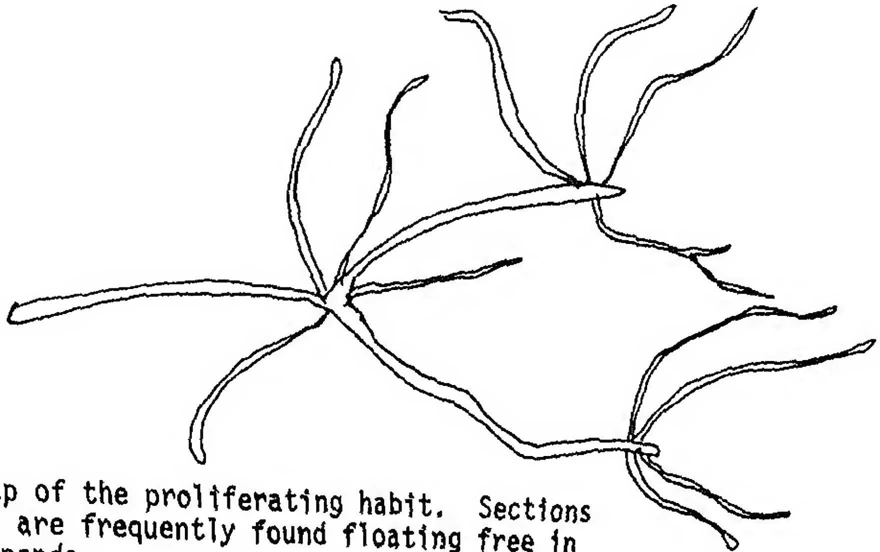
Leaves - Upper floating ones elliptical to oval, generally small (one species has very large leaves 3-10 inches long) 1/2-2 inches. The surface is waxy. In some cases the upper leaves may be missing. Lower leaves very narrow 1-2 mm. or less and strap-like.

Stems - Thin but strong, varying in length, according to water depth. Always rooted.

Fruit - The small cylindrical seed heads are on separate stalks, sometimes appearing above the water or generally found in the axil of the leaves. These seeds are avidly taken by ducks.

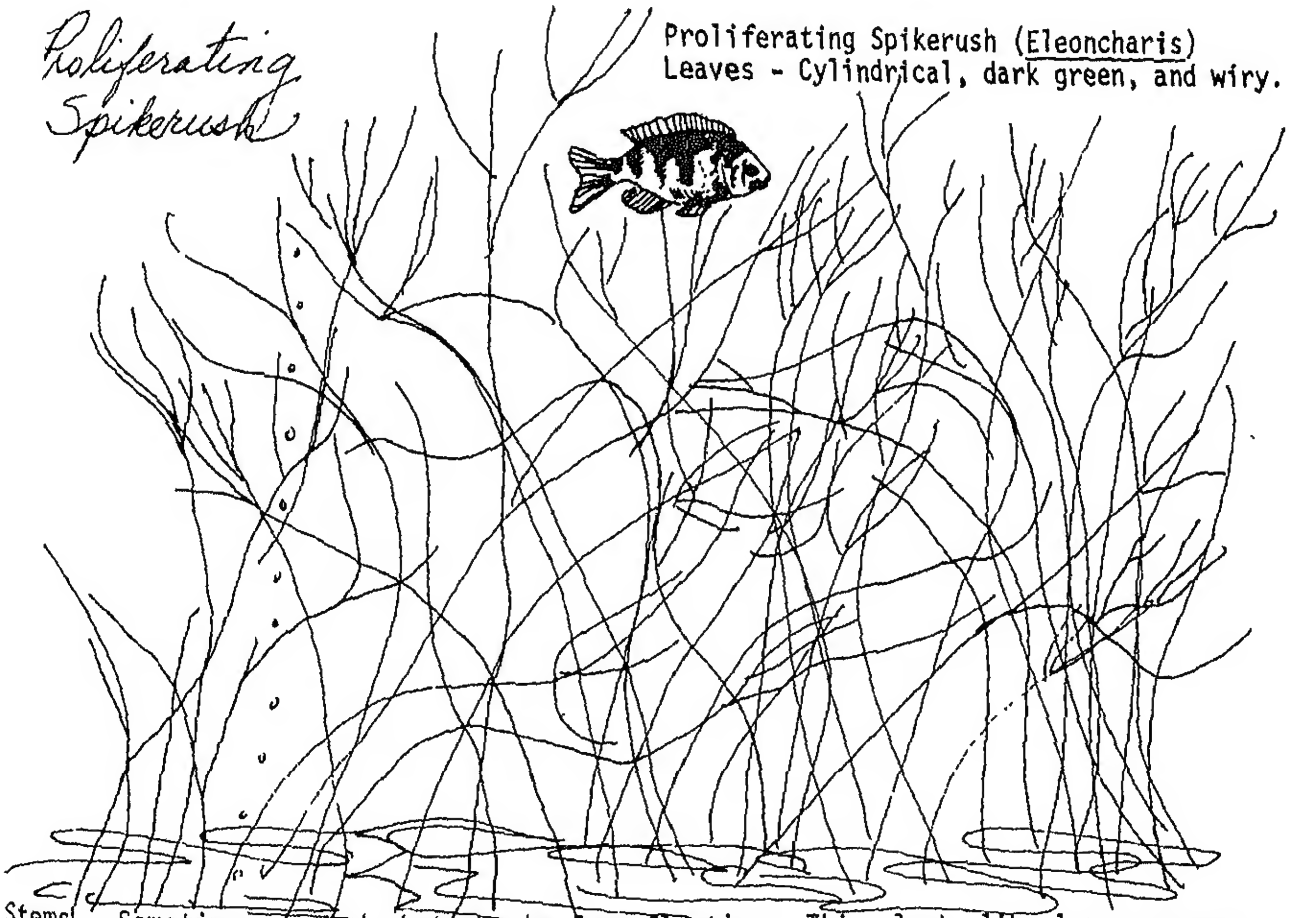
Special Characteristics - The only plant having leaves this small floating on the surface of the water.

Habitat - Any body of water.



A close up of the proliferating habit. Sections like this are frequently found floating free in infested ponds.

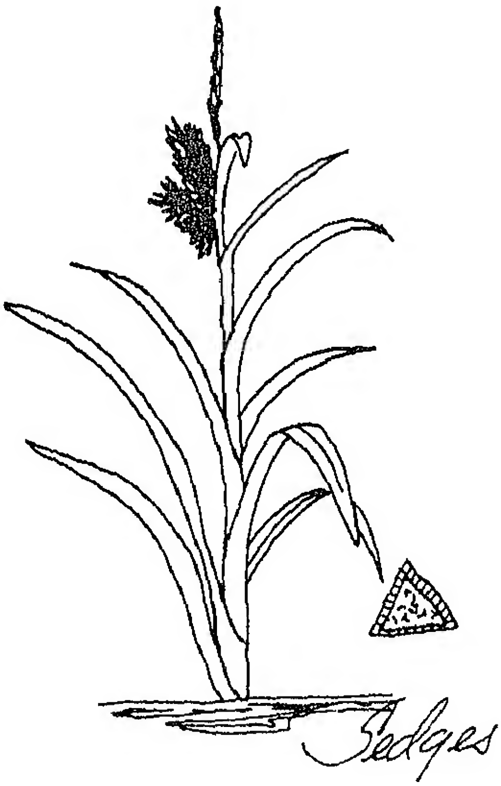
Proliferating Spikerush

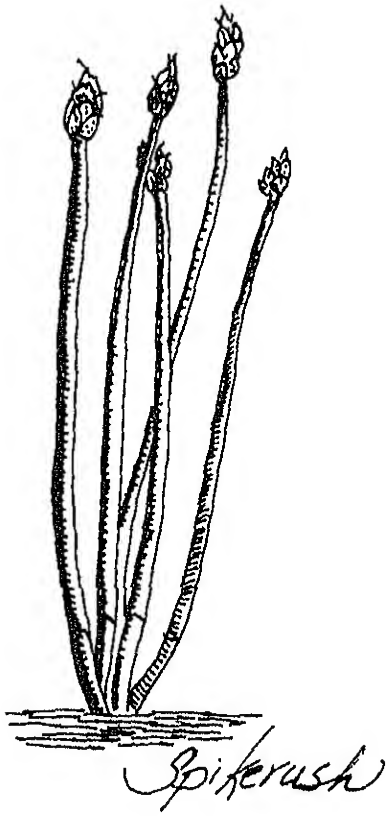


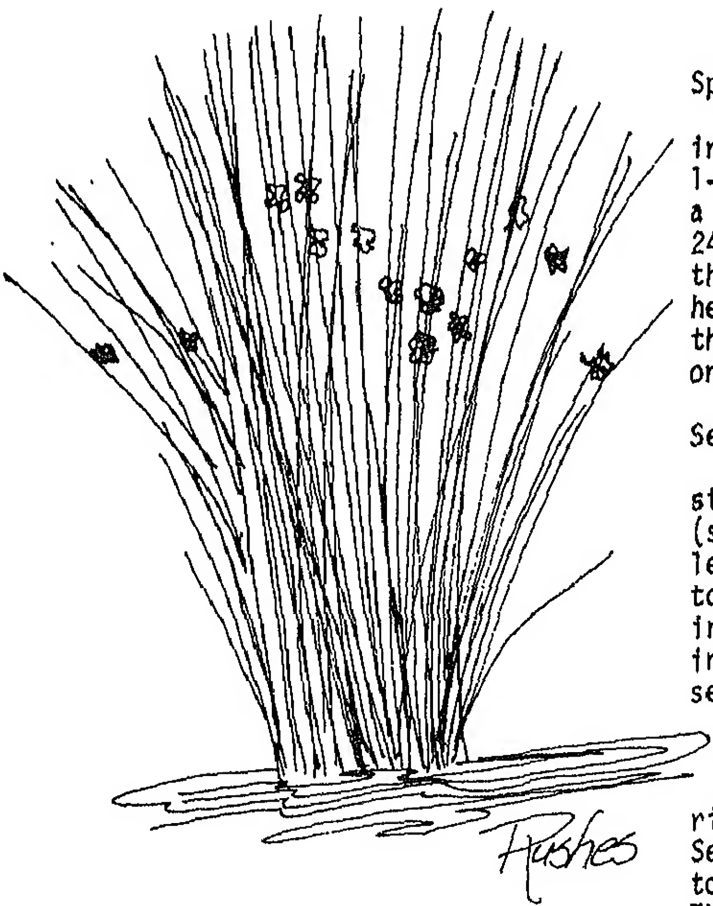
Proliferating Spikerush (Eleoncharis)
Leaves - Cylindrical, dark green, and wiry.

Stems - Sometimes rooted, but may be free-floating. This plant, like Juncus repens, has a proliferating habit, where the stem or leaves may vegetatively produce new plants until the plant is one great branching tangle. It is a difficult one to identify for the amateur since it doesn't resemble much of anything when taken from the water. When this plant is grown on land, it resembles any of the spikerushes.
Habitat - shallow water.

FIGURE 27



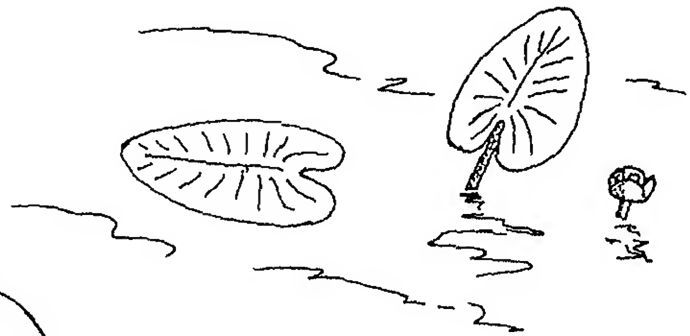




Spikerush (Elecharis) - Upper right
The round stems, without leaves, growing in or out of the water are generally low, 1-10 inches. The tallest of this group has a square stem in cross section and may be 24 inches tall. The "flowers" appear in the summer in small, oval, brownish seed heads at the tip of the stems. Ducks take the seeds of this plant and the tubers found on the roots of one species.

Sedges (Carex and others) - Upper left
Grass-like plants with solid (pith-filled) stems that are triangular in cross section (see illustration). The sheaths of the leaves are closed and tightly attached to the stem. Flowering heads are "prickly" in appearance, cylindrically or spherically in shape. Leaves are "V" shaped in cross section.

Rushes (Juncus sp.) - Lower Left
The dark green stems (leaves) are cylindrical in cross section and pith filled. Seed heads are in drooping clusters attached to the stem 1 to 6 inches below the tip. These plants grown in dense clumps when mature and are found in or out of the water. Clumps may grow as tall as 4 feet, but usually are 2 to 3 feet in height.



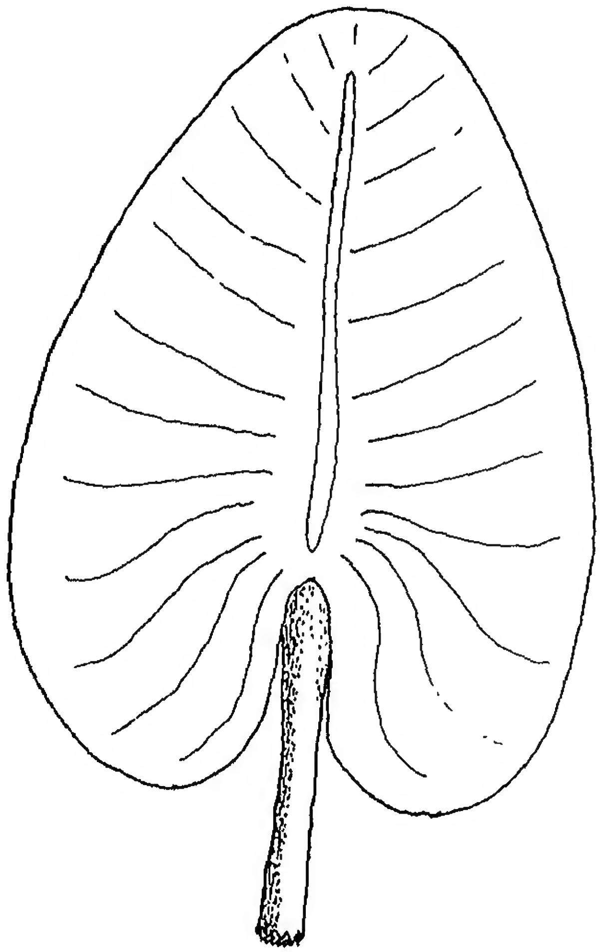


FIGURE 28

Spatterdock, Yellow Waterlily (Nuphar)
The large, waxy leaves are heart-shaped and may be upright or floating on the surface. The stems are thick, strong, and elastic. The small flowers are yellow and waxy in appearance. This plant is found in the shallows out to a depth of 3 or 4 feet.

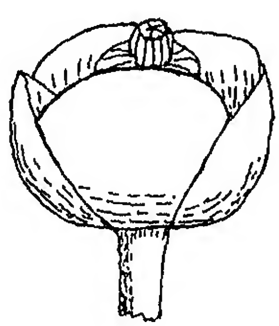


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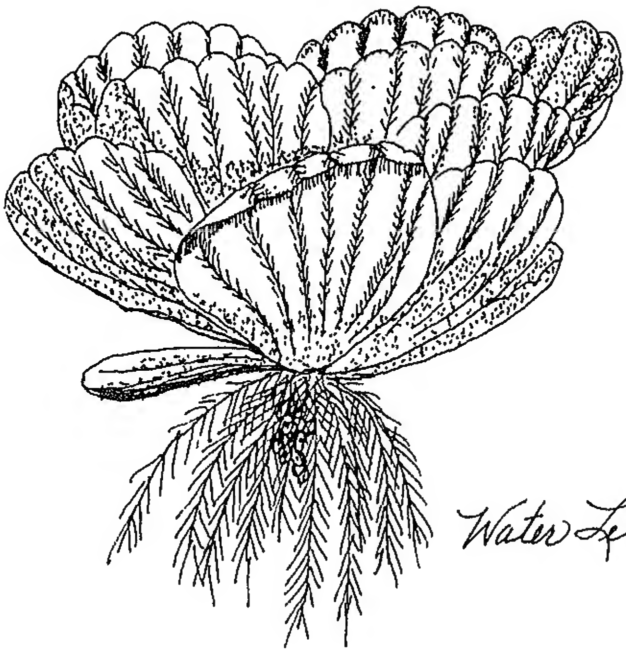
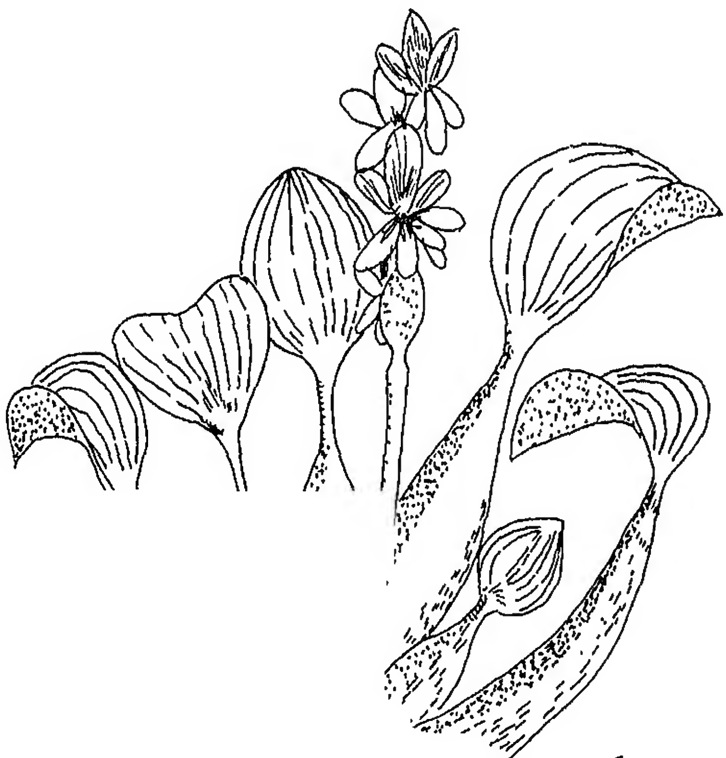
FIGURE 29



Water Lettuce

Water lettuce (Pistia) Free floating on bayous, canals and ponds in the southern part of the state. Looks very much like a "relaxed" head of lettuce with the leaves open and green all the way to the base. Leaves strongly ribbed and pubescent, gray-green in color and spongy feeling.



Water hyacinth

Water hyacinth (Eichhornia) Free floating or standed: on rivers, ponds, bayous, swamps and marshes. Leaves glossy green and rounded to kidney shaped with inflated bases. A few to many leaves to the plant; frequently growing to the height of 18 to 24 inches high, usually lower. Flowers 6 petaled, whitish blue to punple. The uppermost darker with a yellowish teardrop shaped "eye". A few to many flowers per stalk.

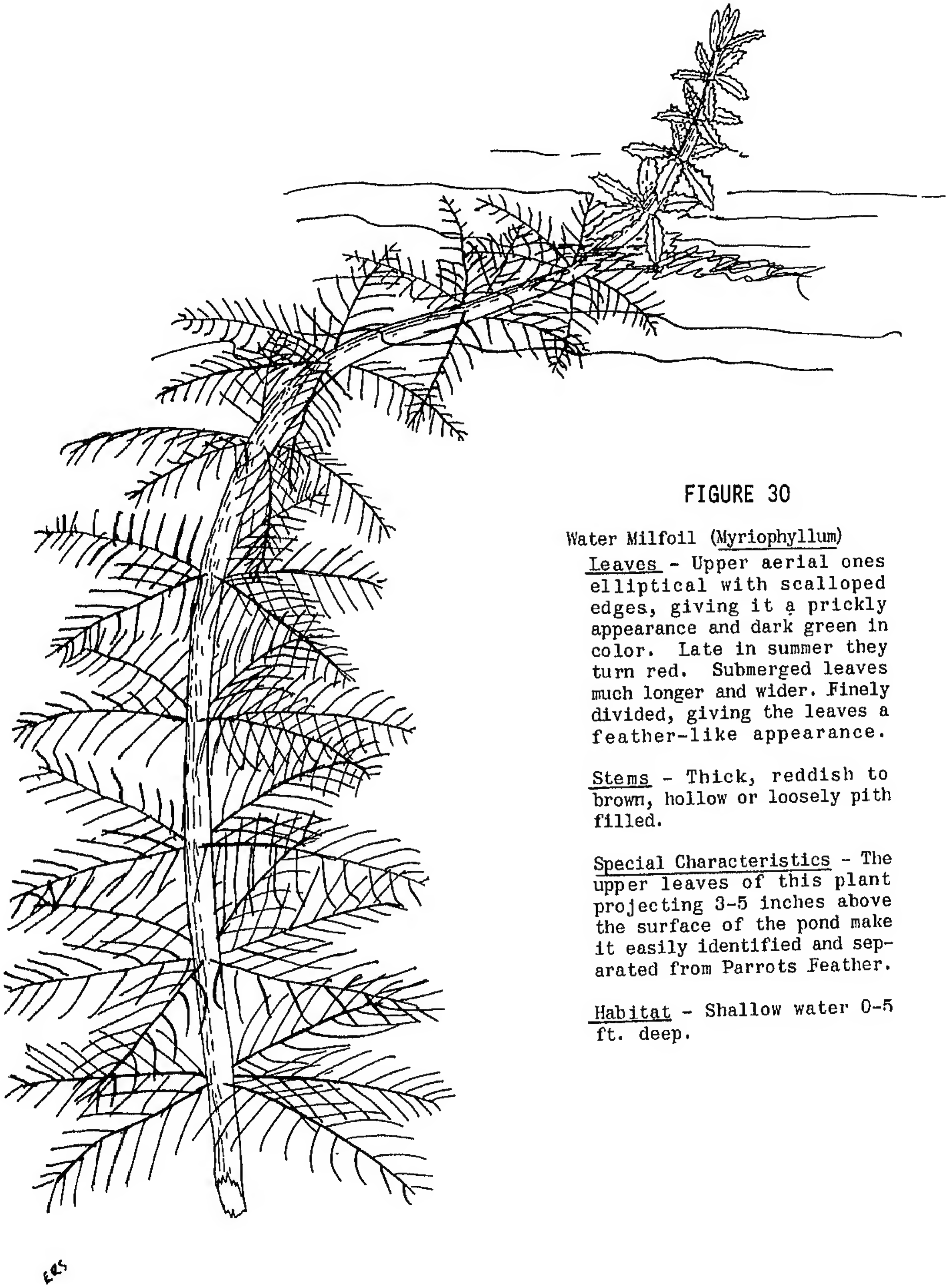


FIGURE 30

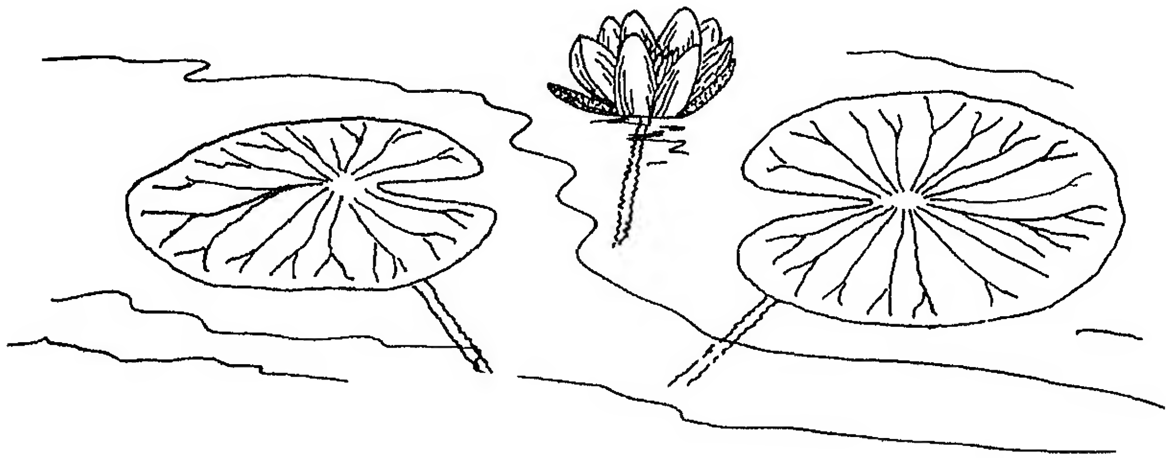
Water Milfoil (Myriophyllum)

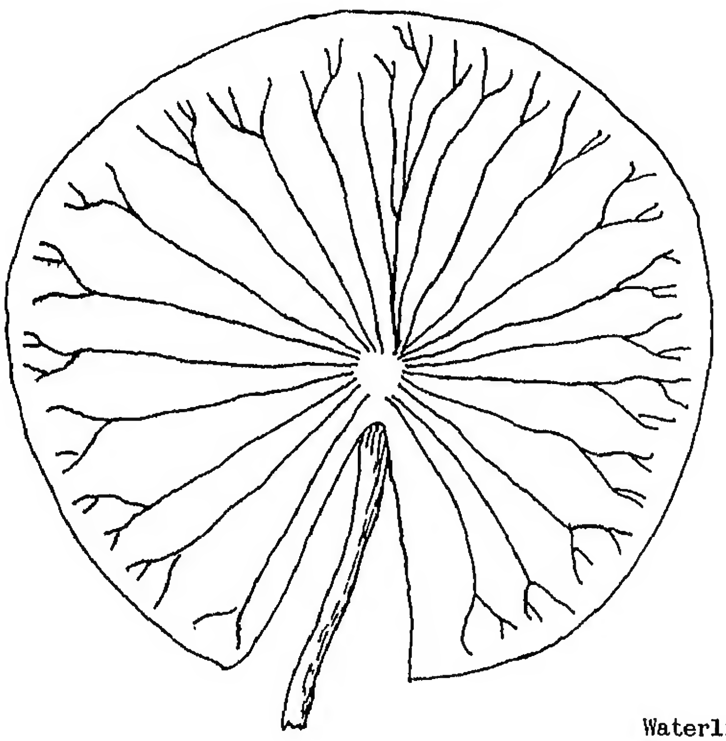
Leaves - Upper aerial ones elliptical with scalloped edges, giving it a prickly appearance and dark green in color. Late in summer they turn red. Submerged leaves much longer and wider. Finely divided, giving the leaves a feather-like appearance.

Stems - Thick, reddish to brown, hollow or loosely pith filled.

Special Characteristics - The upper leaves of this plant projecting 3-5 inches above the surface of the pond make it easily identified and separated from Parrots Feather.

Habitat - Shallow water 0-5 ft. deep.





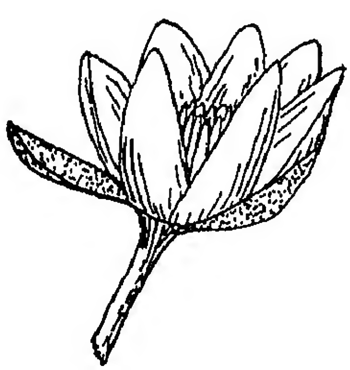


FIGURE 31

Waterlily (Nymphaea)

The large circular waxy floating leaves are deeply notched and borne on tough elastic stems. The large white, pink, yellow or blue flowers, with 12-40 petals, float on the surface with the leaves. The thick intertwining roots of this plant form extensive mats over the bottoms.

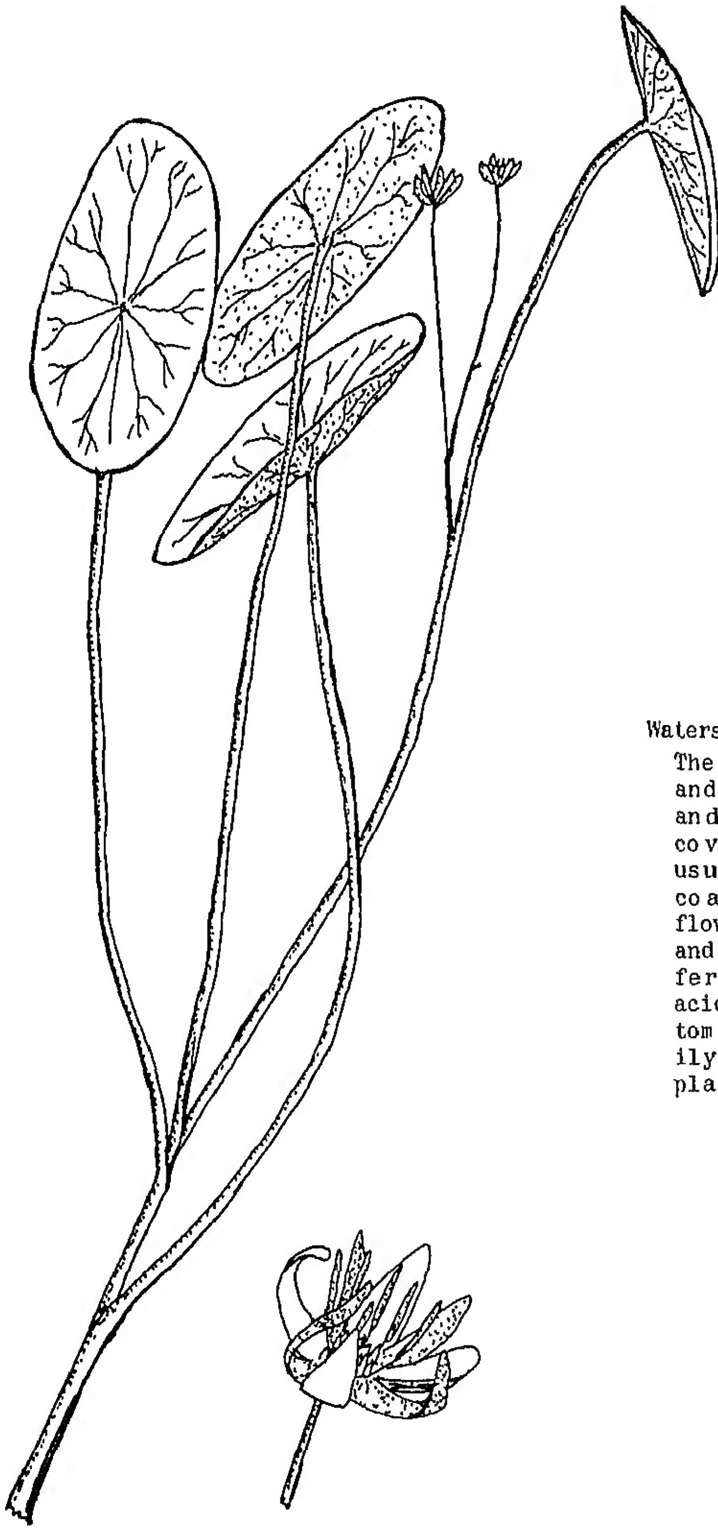


FIGURE 32

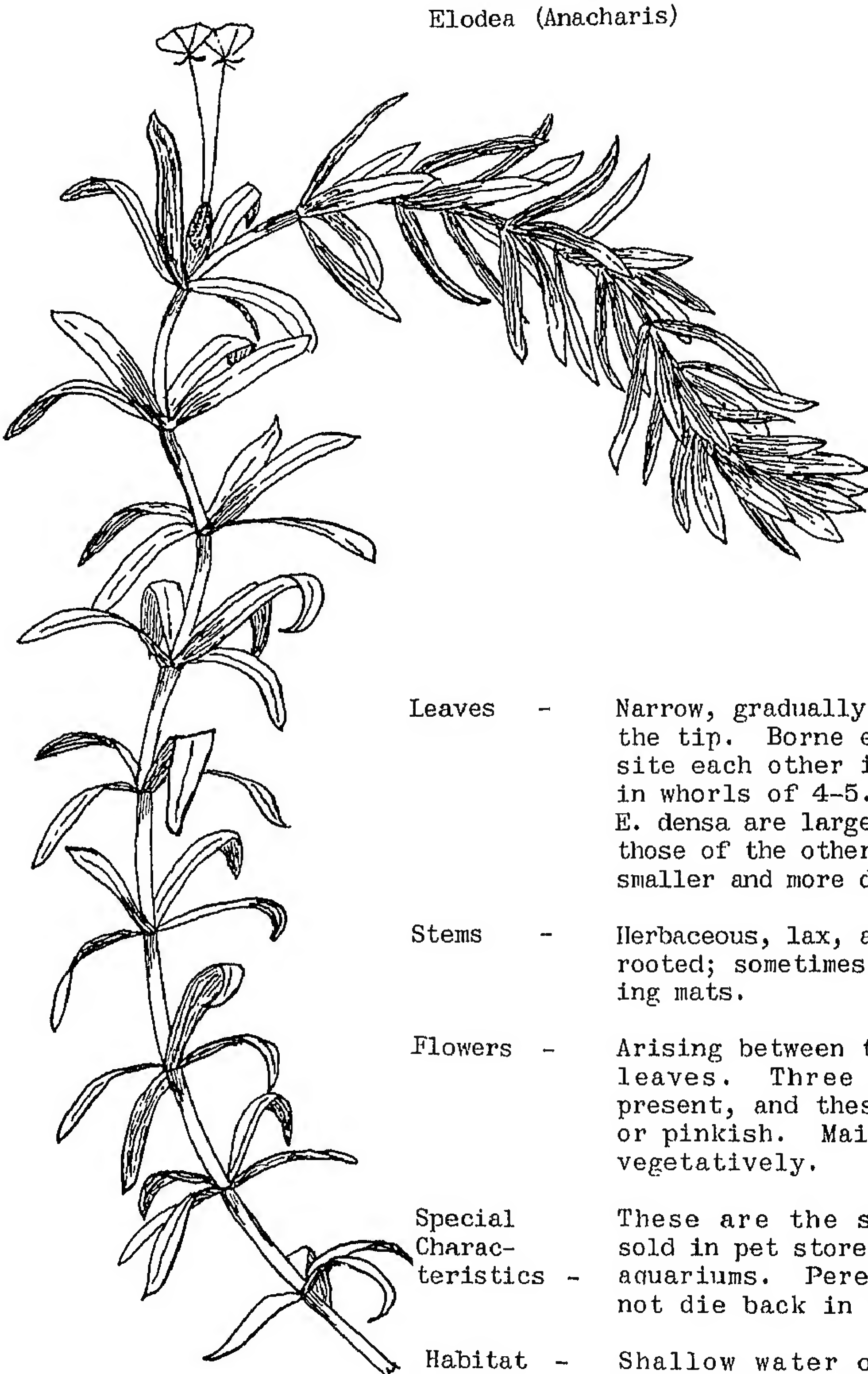
Watershield (Brasenia)

The floating leaves are oval and the undersides reddish and covered with a shiny covering. The stems are usually covered with this coating also. The small flowers are reddish to purple and have 3 to 4 petals. Prefers ponds or slow-moving acid water, with a sandy bottom. Some diving ducks readily take the seeds of this plant.

FIGURE 33

WATERWEED

Elodea (Anacharis)



Leaves -	Narrow, gradually tapering to the tip. Borne either opposite each other in pairs, or in whorls of 4-5. Leaves of E. densa are large and coarse; those of the other two species smaller and more delicate.
Stems -	Herbaceous, lax, and generally rooted; sometimes form floating mats.
Flowers -	Arising between the stem and leaves. Three petals are present, and these are white or pinkish. Mainly spreads vegetatively.
Special Characteristics -	These are the same plants sold in pet stores for use in aquariums. Perennial, does not die back in the winter.
Habitat -	Shallow water of lakes or ponds.

Identification Of Aquatic Weeds

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essor (Fisheries), Auburn University Agricultural Experiment Station, Auburn, Alabama, and Research Agronomist, ›s Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plantation Field Laboratory, Fort Lauderdale, Florida

Introduction

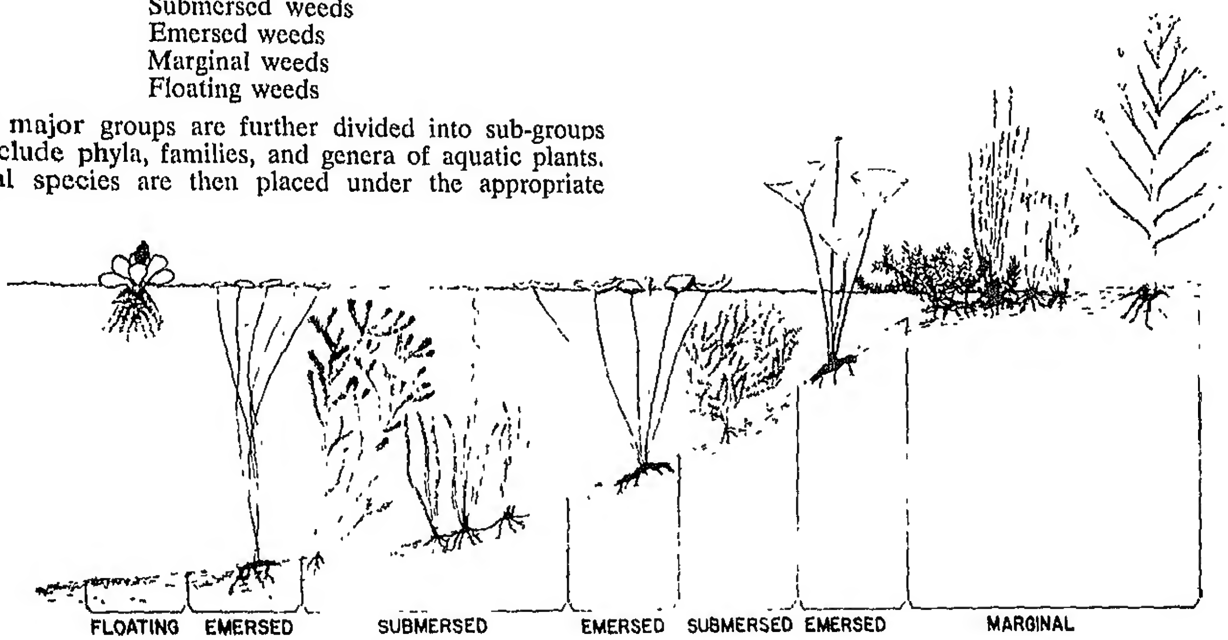
ıuatic plant growths in any body of water create problems ved with practically all water uses. A knowledge of the ity of over one-hundred species of aquatic plants which ısly affect water resources is necessary if effective and :nt control practices are to be employed. Since botanists not be available to name every species of plant involved particular aquatic weed problem, the following simple le of the major plant groups based upon their size, shape, ɛrowth habits has been developed:

- Plankton algae
- Filamentous algae
- Submersed weeds
- Emersed weeds
- Marginal weeds
- Floating weeds

hese major groups are further divided into sub-groups h include phyla, families, and genera of aquatic plants. vidual species are then placed under the appropriate ra.

Descriptions of these major groups, including a listing of the common and scientific name of many of the plant species in each group, and a descriptive illustration of some of the most important species are given in this paper.

The intent of this paper is not to present a taxonomic classification of aquatic plants. Rather, it is an attempt to set forth groupings of plants based upon morphological characteristics and occupancy of ecological niches that may be useful to a majority of persons involved in aquatic plant control at the present time.



SPATIAL RELATIONSHIPS OF ROOTED AQUATIC PLANTS

ALGAE

The freshwater algae are diverse in shape, color, size, and ıitat. Some authorities have divided these algae into as ıy as nine phyla. A description of all species of algae ıld be as comprehensive as writing about all land plants, sses, ferns, fungi, and seed plants.

For practical field work the algae are divided into two ups, plankton and filamentous algae, and are characterized their growth form.

PLANKTON ALGAE

This group, sometimes called phytoplankton to separate em from the microscopic animal forms called zooplankton, clude the truly aquatic, microscopic, single-cell, colonial, ıd simple filament forms of plants. They are the basic link the conversion of inorganic constituents in water into organic matter. The rate at which this conversion occurs depends upon the abundance of algae in a given area at a given time. When present in sufficient numbers these plants impart colors to the water varying from green to yellow to red to black. They may also congregate at or near the water surface and form so-called "water blooms", or "scums".

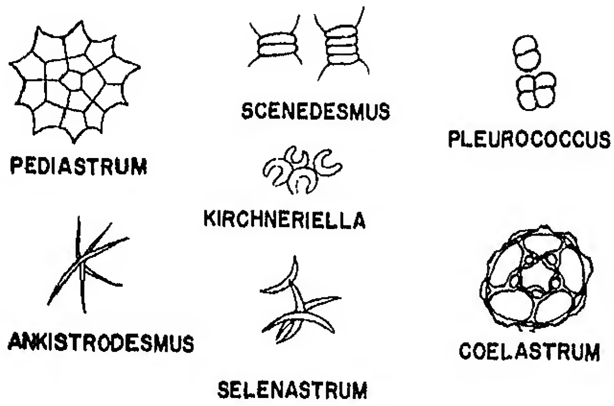
Based upon their taxonomic characters, the major plankton algae have been separated into the following phyla:

GREEN ALGAE

Chlorophyta (Green algae). Unicellular or colonial, cells contain plastids in which chlorophyll is predominant.

Chrysophyta (Yellow-green or Yellow-brown algae). Including diatoms and desmids. Unicellular or colonial. Pigment in chromatophores in which yellow or brown often predominates. Diatoms appear more abundant in colder waters.

Euglenophyta (Euglenoids). Cells solitary, swimming by one (1) or two (2) flagella. A gullet and eye spot (red) present at anterior end of many species



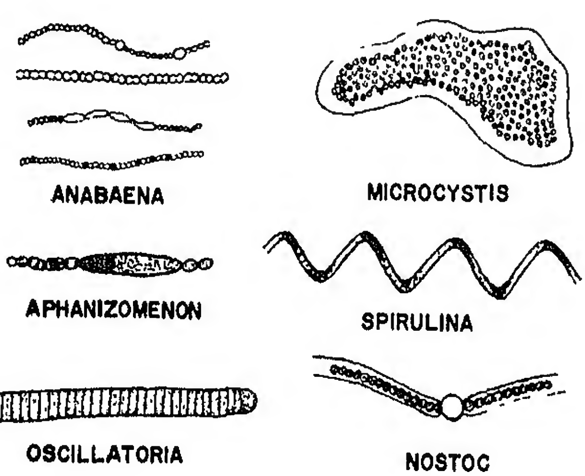
BLUE GREEN ALGAE

Cyanophyta (Bluegreen algae). Unicellular or colonial, or simple filaments. Pigment in solution and coloring entire protoplast. Cell wall thin often covered with gelatinous sheath.

Cryptophyta. Cells solitary or colonial, swimming by means of 2 lateral or sub-apical flagella. Chromatophores large and brown.

Pyrrhophyta (Dino-flagellates). Cells solitary, swimming by means of 2 flagella, one commonly wound transversely around cell and the other extended posteriorly from point of flagella attachment.

Diatoms are most abundant in spring and fall (50°-60°F. optimum water temperature), the green algae are most abundant when water temperatures are 60°-80°F., and the blue-green algae are never abundant at water temperatures less than 70°F.



Biologist and engineers concerned with various management and utilization processes of waters often separate these algae into the following groups:

- Algae producing tastes and odors in water.
- Algae producing scum and slime growths in water areas.
- Algae causing coloration of waters.
- Algae causing corrosion of concrete and steel in contact with water.
- Algae causing interference in coagulation processes.
- Algae producing substances toxic to animal life.
- Algae that are parasitic to plant and animal life.

A major beneficial role of plankton algae is removal of carbon dioxide from the water in the process of photosynthesis during daylight, and the production of oxygen as a by-product of photosynthesis.

FILAMENTOUS ALGAE

Members of this group of algae belong primarily to the phylum Chlorophyta. These plants are filaments of single cells united end to end, and may appear as a single thread, as branched filaments, as a net, or as erect, stem-like, whorled branches with forked "leaves". These plants have no true roots, stems or leaves.

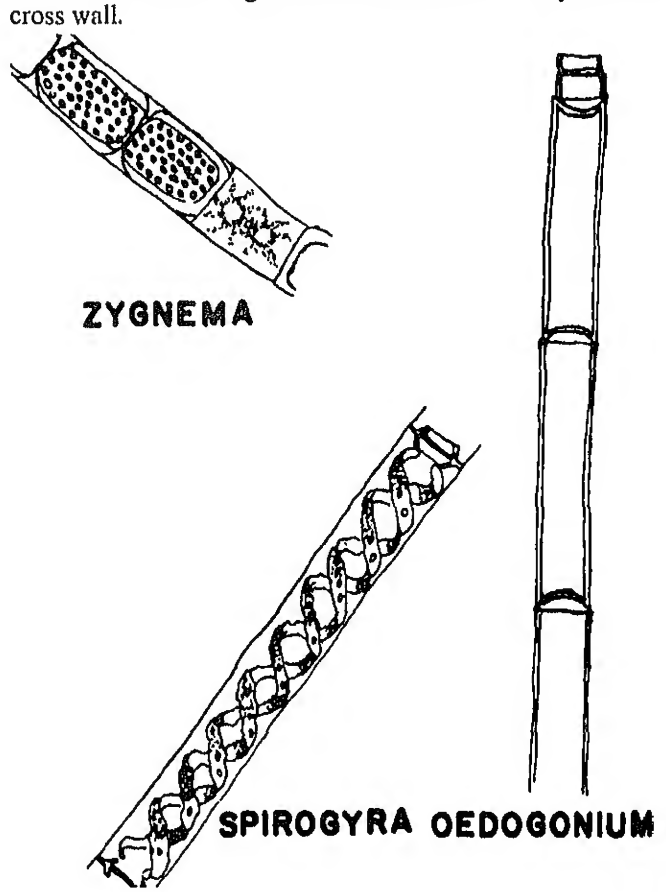
Certain of the attached or supported single filament forms which grow in cooler weather have been utilized as control measures for certain rooted submersed aquatic weeds in fish ponds. Since these algae die at onset of hot weather, their death seemingly triggers the death of the supporting higher plants.

Other species of single as well as branched filament forms grow in both cool and warm weather and are generally considered a nuisance in whatever body of water in which they occur. Distribution of species of the following genera of algae seemingly is rather general throughout the United States:

Zygnema—Single filament form of algae, each cell with two star-shaped chloroplasts. Some species with conspicuous gelatinous sheath.

Spirogyra—Single filament form of algae. Diameter cells very small to fairly large. Chloroplast in cells definitely spiraled. May form green clouds of cottony growths in still waters.

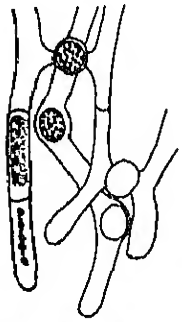
Oedogonium—Single filament form in which cells are not cylindrical, being slightly larger at anterior end. Always with one or more ring-like scars at anterior end just below cross wall.



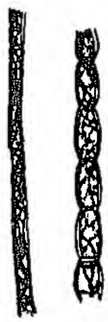
Mougeotia—Single filament form of algae with 1 band-like chloroplast per cell.

Rhizoclonium—Mainly single filament, coarse, wiry, form of algae. Cells slender usually three or more times as long as their diameter.

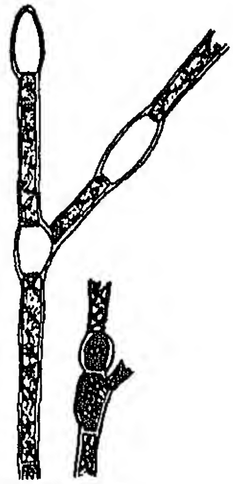
Pithophora—Irregularly branched filaments with barrel-shaped akinetes scattered throughout the filaments. Texture of filaments coarse, feeling like wet cotton to touch.



MOUGEOTIA



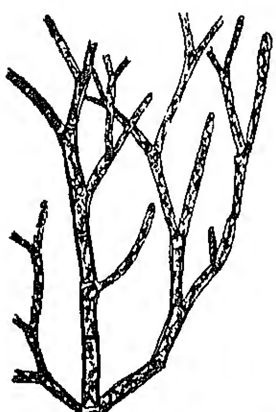
RHIZOCLONIUM



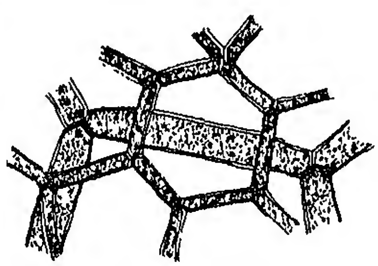
PITHOPHORA

Cladophora—Irregularly branched form of algae with cylindrical cells and without barrel-shaped akinetes. May form cladophora balls under northern conditions.

Hydrodictyon—Cells united at each end to form a network. Nets become extensive due to reproductive capacity of each cell to form a new net. Reported in ancient Chinese literature.



CLADOPHORA



HYDRODICTYON

Chara—Plants large, with erect stem-like whorled branches and forked leaves that are rough to the touch. Crushed plants produce musk-like odor.

Nitella—Plants large with erect, stem-like, whorled branches and forked leaves that are delicate in appearance and not rough to touch. Crushed plants do not produce musk-like odor

CHARA

NITELLA

SUBMERSED WEEDS

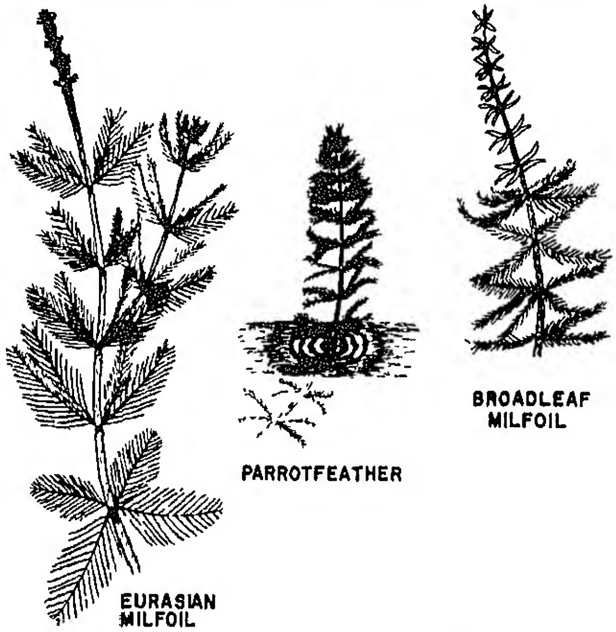
The plants included in this group are those rooted aquatics which produce all or most of their vegetative growth beneath the water surface. Most members of this group have true roots, stems, leaves, and produce seeds. In many instances these plants have an underwater leaf form, a totally different floating or emersed leaf form, and produce their flowers on an aerial stalk. Abundance of growth of these weeds is dependent upon depth and turbidity of water, and type of bottom. For most submersed plants a maximum depth of 8 to 10 feet in clear waters is the limit of their habitat.

Most of these submersed aquatic plants are capable of absorbing nutrients as well as herbicides through either their roots or vegetative growth.

Major obnoxious weeds in this group with a brief description of each family are as follows:

Watermilfoil Family—*Haloragidaceae*. Perennial aquatics, submersed with slender sparingly branched stems rooting freely at lower nodes. Leaves whorled, variable from pinnately dissected into filiform segments to those reduced to bracts, leaf dissection variable from submersed to emersed forms. Flowers very small, borne either in axils of emersed leaves or bracts. Members of this family fairly well distributed throughout the United States.

Eurasian milfoil — *Myriophyllum spicatum*
Parrotfeather — *Myriophyllum brasiliense*
Broadleaf milfoil — *Myriophyllum heterophyllum*

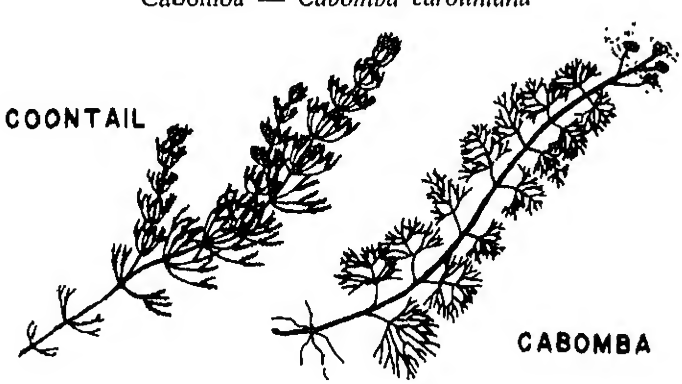


Hornwort Family — *Ceratophyllaceae*. Submersed, rootless aquatic plants with slender main branch and scattered lateral branches. Lower end of stem frequently anchored in bottom mud. Leaves in whorls on stem, divided into slender, stiff, hooked, segments that are crowded toward apex by shortening of internodes to give shoots the "coontail" appearance. Only one genus but well distributed over the United States.

Common Coontail — *Ceratophyllum demersum*

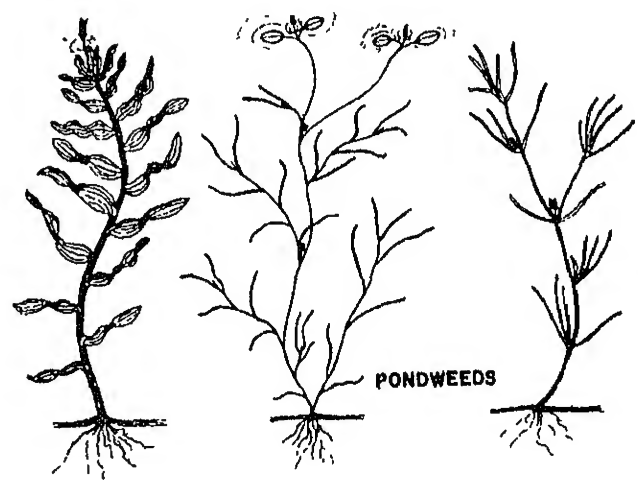
Waterlily Family — *Nymphaeaceae*. Submersed aquatic plant with slender, branched stem, opposite or whorled, finely dissected leaves and with upper leaves that are entire and oblong and floating on surface. Flowers small, solitary on axillary peduncle and generally emersed. One species, widespread over eastern half of United States.

Cabomba — *Cabomba caroliniana*



Pondweed Family — *Potamogetonaceae*. Fresh or brackish water submersed aquatic plants with creeping rootstocks. Leaves mostly alternate, may be opposite, on erect jointed stems. Leaves all alike or may be 2 kinds, all submersed or some of them floating. Submersed leaves thin and linear or all broad, emersed leaves broad, more or less elliptical and petioled. Seed heads small and crowded into spikes. Spikes raised to surface on long peduncle and/or submersed on short peduncle. Winter buds produced in axils of leaves of some species, creeping rootstocks of other species may terminate in small tubers. The largest family of truly aquatic plants, widely distributed throughout the United States, and one of the most troublesome groups of submersed aquatic plants.

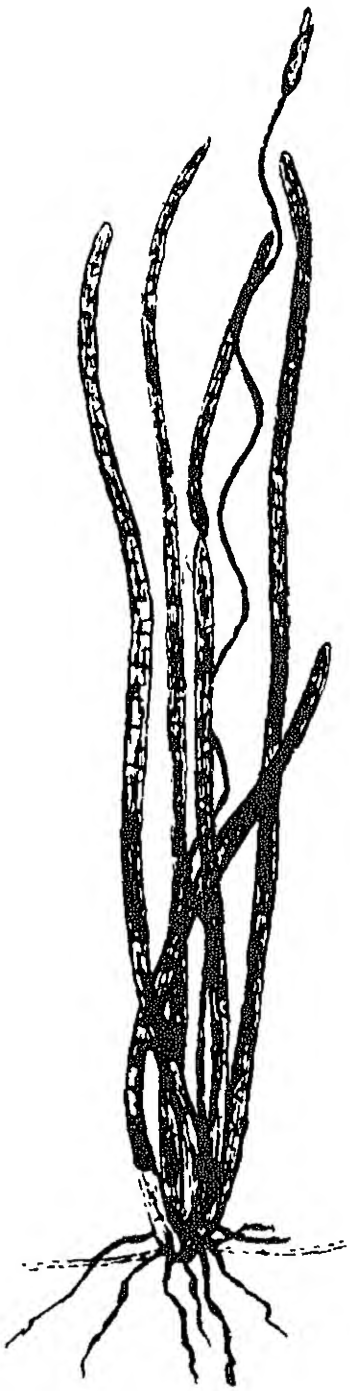
Pondweeds — *Potamogeton* spp.
Sago pondweed — *P. pectinatus*
Waterthread pondweed — *P. diversifolius*
Curlyleaf pond — *P. crispus*
Widgeon grass — *Ruppia maritima*
Horned pondweed — *Zannichellia palustris*



Frogbit Family — *Hydrocharitaceae*. Perennial, slender-stemmed, branching, submersed aquatic plants with whorled thin linear leaves and fibrous roots, or submersed plants with long, linear clustered leaves at nodes of rhizomes. Flowers borne on peduncle above surface of water.

Brazilian waterweed — *Elodea densa*
American waterweed — *E. canadensis*
Eelgrass — *Vallisneria americana*

ELODEA



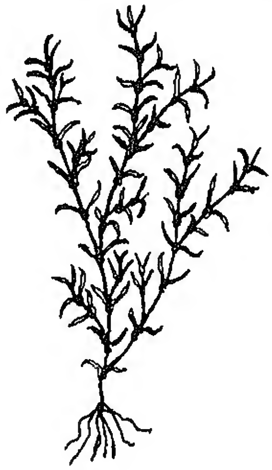
EELGRASS

Naiad Family — *Najadaceae*. Submersed aquatic plants with slender branches and fibrous roots. Leaves opposite or crowded into apparent whorls, finely toothed, dilated at base often with prominent stipules. About 35 species inhabiting fresh or brackish waters of temperate and tropical regions.

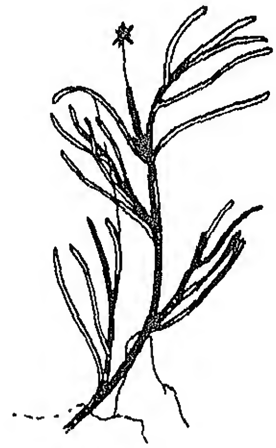
Naiads — *Najas* spp.
Southern naiad — *N. guadalupensis*
Slender naiad — *N. flexilis*

Pickerelweed Family — *Pontederiaceae*. Perennial or annual, floating or rooted aquatic plants with creeping rootstocks and fibrous roots. Leaves linear and thin on slender, branched, leafy stems. Flowers mostly solitary, appearing star-shaped, borne on spathe above water. Members of this family widely distributed throughout the United States.

Waterstargrass — *Heteranthera dubia*



NAIAD

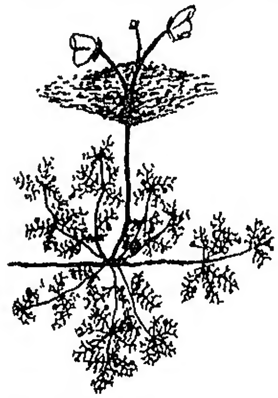


STARGRASS

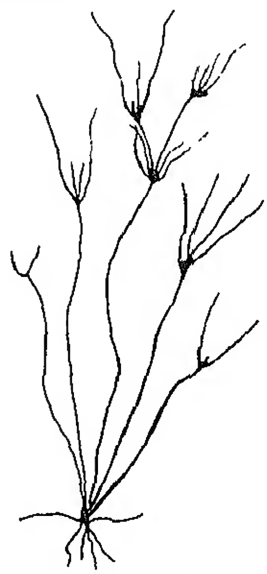
Bladderwort Family — *Lentibulariaceae*. Submersed or floating, rootless plants with flaccid, finely dissected or filiform simple leaves. Many of leaf segments with small bladders that have little trap doors. These bladders may trap small aquatic animals which are digested and may serve as partial nourishment for the plant. Solitary flowers appear above water on short, erect pedicel and are either yellow or purple in color.

Bladderworts — *Utricularia* spp.

Sedge Family — *Cyperaceae*. Perennial plants having general appearance of grasses, fibrous roots and solid stems, submersed stems may root at joints. Leaves linear, parallel-veined, basal or alternate on stem, and with closed sheath.



BLADDERWORT



NEEDLE RUSH

Flowers borne in axils of scales (glumes) in spikelets. Single species but with many varieties, distributed throughout the United States.

Slender Spikerush (Freshwater needle rush) — *Eleocharis acicularis*

EMERSED WEEDS

This group includes those plants that are rooted in the bottom muds and produce a majority of their leaves and flowers at or above the water surface. Some species possess leaves that are flat and float entirely upon the water surface. Other species have leaves that are saucer-shaped or whose margins are irregular or fluted. These latter types of leaves do not float entirely upon the water surface. Rather, they offer sheltered water areas beneath the leaf that are suitable habitats for mosquitoes. Leaf size and point of attachment is also variable in this group. Size ranges from a diameter of 2 inches to as much as 18 inches. Point of stem attachment may be at the leaf margin or within the leaf margin. The presence of these floating-leaf species provides sufficient shade to eliminate a suitable habitat for submersed weeds. These plants occupy clear water areas to depths of 10 feet or more.

Since emersed weeds and submersed weeds prefer the same type habitat, the elimination of emersed weeds usually will permit submersed weeds to become established. The advisability of emersed weed control depends upon the proposed management of a water area. While it is cheaper to control emersed weeds, it is generally conceded that certain of the floating, flat-leafed weeds produce fewer problems with water management than do the partially floating-leaf species or the submersed weeds.

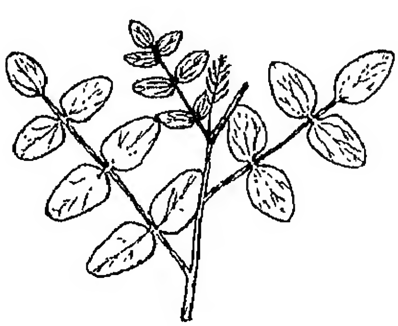
The major obnoxious weeds in the emersed group with a brief description of families are as follows:

Cress Family — *Cruciferae*. Perennial aquatic herb with creeping stems, rooting at nodes. Leaves alternate and pinnately compounded, with peppery flavor. Introduced from Europe, but distributed over most of United States.

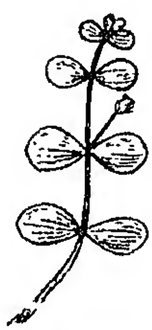
Watercress — *Nasturtium officinales*

Figwort Family — *Scrophulariaceae*. Creeping, fleshy herbs, rooting at nodes, leaves opposite, borne on stem and entire. Stems may be covered with crinkled hairs, flowers solitary, pale blue, purple, or white, borne on short stalk in axils of leaves.

Water Hyssop — *Bacopa caroliniana*



WATERCRESS



WATER HYSSOP

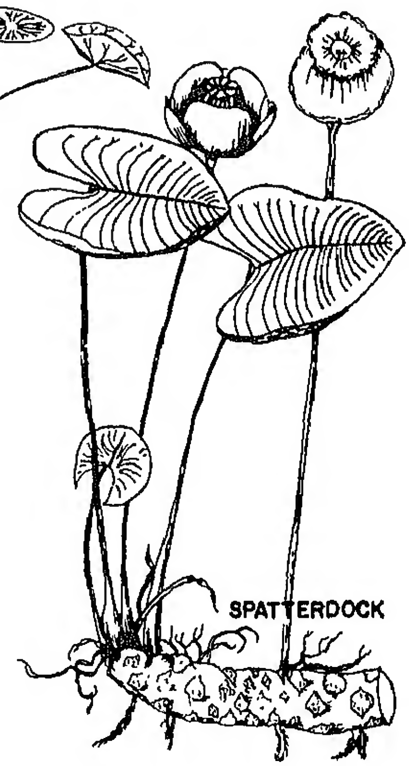
Waterlily Family — *Nymphaeaceae*. Perennial aquatic plants with large, creeping, often branched, rootstocks. Leaves may be large, elliptical or ovate in shape, sometimes emersed sometimes floating, submersed portions of stems and underside of floating elliptical leaves of one species covered with mucilaginous material. Flowers may be solitary and emersed or floating, or small and emersed.

Banana waterlily — *Nymphaea mexicana*
Fragrant waterlily — *N. tuberosa*
Spatterdock — *Nuphar advena*
American lotus — *Nelumbo lutea*
Watershield — *Brasenia schreberi*

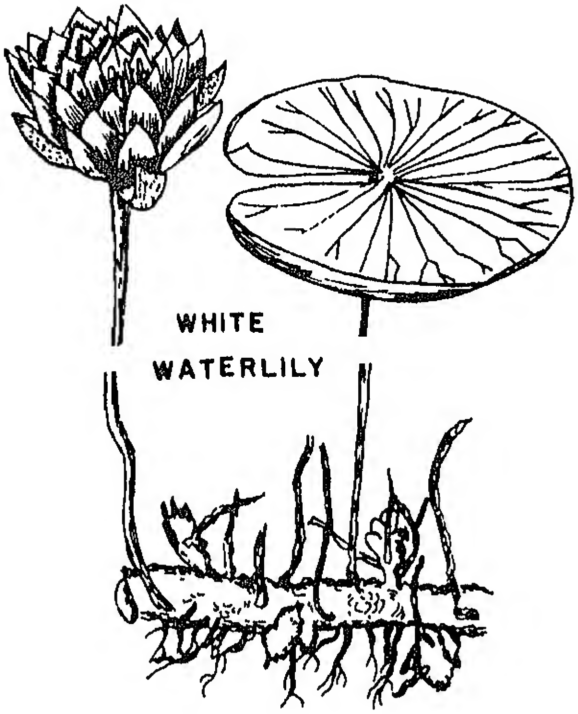
Watershield has elliptical, flat, floating leaves that have a mucilaginous covering on the underside of leaves and submersed stems. There are few mosquito problems connected with watershield growths since the leaves are flat on water surface.

Spatterdock has similar habitat requirements to white water-lilies. The leaf is more heart-shaped and the flowers are almost oval with a distinctive seed case.

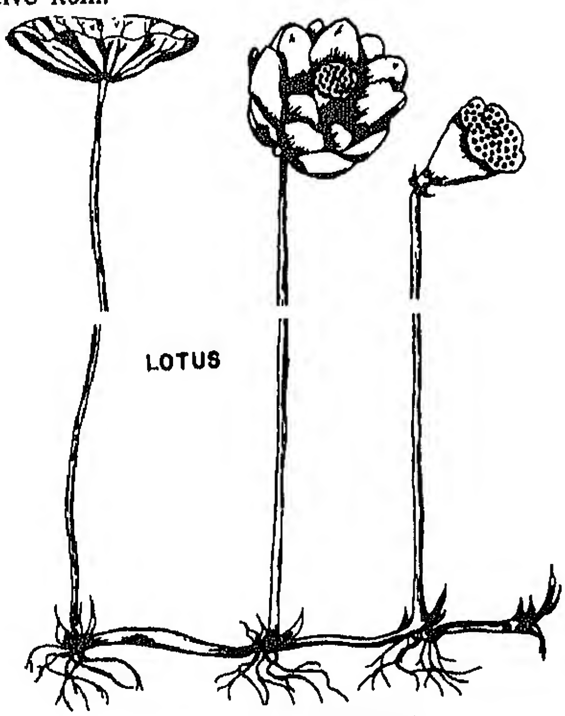
WATERSHIELD



SPATTERDOCK



American lotus is probably the largest of the aquatic plants. It has large, emersed, leaves that are inverted like a saucer. The flower is relatively large, borne on an emersed stalk. The seed head is unique-being used in the dry state as a decorative item.



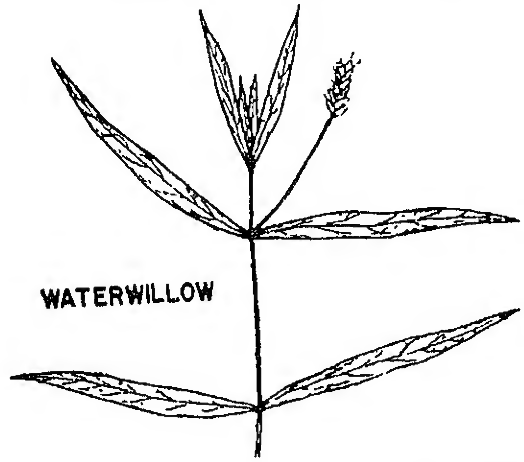
MARGINAL WEEDS

The species comprising this group are the most obvious and probably the most widely distributed of rooted aquatic plants. Members of this group are variable in size, shape, and preference of habitat. Many species are adapted to grow from moist shore-line soils into water up to 2 feet in depth. Others are limited to the moist soil habitat, while still others are confined almost entirely to a watery habitat.

The variations in composition of marginal species includes members of the broadleaf types, herbs, grasses, and trees. Major obnoxious species of marginal growth with brief description of families are as follows:

Acanthus Family — *Acanthaceae.* Perennial herbs with creeping rootstocks, and erect stems, leaves simple and opposite. Only one species limited to eastern United States.

Waterwillow — *Justicia americana*

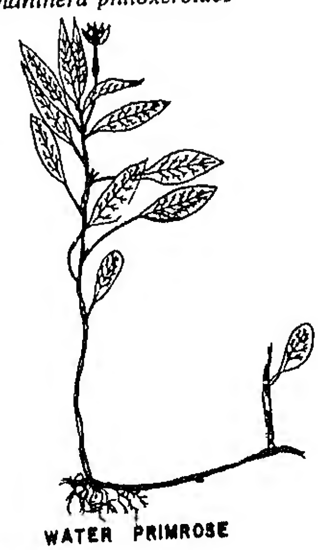


Evening Primrose Family — *Onagraceae.* Perennial herbs with opposite or alternate simple leaves. Seeds borne in a box shaped capsule. Plants may be erect and branched or stems may be creeping and branched, rooting may occur at nodes. Distribution of aquatic members of this family confined mainly to Southeastern United States.

Waterprimroses — *Jussiaea* spp.

Amaranth Family — *Amaranthaceae.* Herb-like plants with opposite, entire, oblong, lanceolate leaves. Stems prostrate and creeping, jointed, branched and often rooted at nodes. Flowers a cluster similar to white clover blossom. May grow on dry land, on wet land into water or may float on water surface. Confined mainly to South Atlantic and Gulf areas.

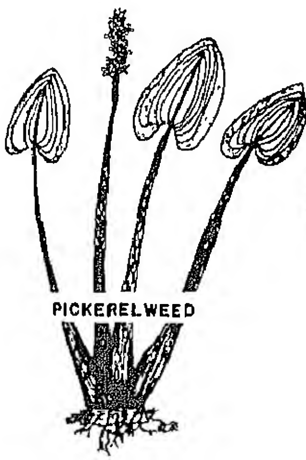
Alligatorweed — *Alternanthera philoxeroides*

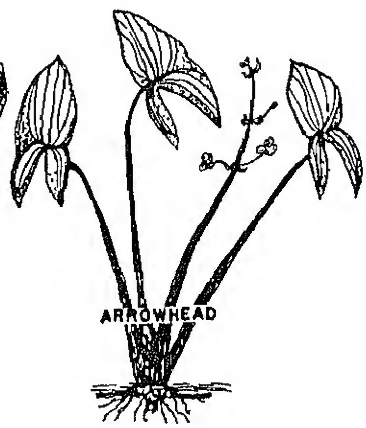


Pickerelweed Family — *Pontederiaceae*. Stout, perennial, aquatic plant with thick, creeping rootstock and fibrous roots. Leaves in basal cluster and erect, with fleshy, sheathing petiole and heart-shaped to lance-shaped blades. Flowers a violet-blue cluster borne on stout erect stalk. Distribution confined to eastern half of United States

Pickerelweed — *Pontederia cordata*

Water Plantain Family — *Alismaceae*. Mostly aquatic perennials with rosettes of sheathing basal leaves and scape-like stems from short, erect, rootstock, rhizomes or tubers, root system fibrous. Leaves variable, with long petioles, emersed or submersed types; submersed leaves subulate and elliptical. Emersed leaves elliptical to sagittate. Flowers on





fruiting stalk and usually white in color. Each underground stem ends in edible tuber.

Arrowhead — *Sagittaria* spp.

Buckwheat Family — *Polygonaceae*. Moist soil perennial or annual plants with jointed stems with swollen nodes and creeping rootstocks, alternate simple entire leaves. Flowers in spikes. A few species of a single genus are aquatic and are distributed over United States.

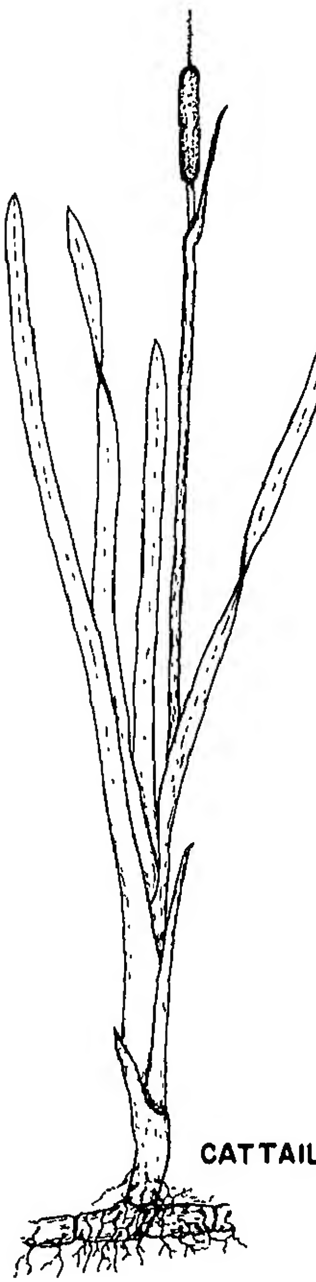
Smartweeds — *Polygonum* spp.

Pepper Family — *Piperaceae*. Tall aquatic plant from slender rootstock, leaves scattered and heart-shaped, flowers white. Confined to eastern half of United States.

Lizzardtail — *Saururus cernuus*

Cattail Family — *Typhaceae*. Tall, erect, perennial plants with simple jointless stems, linear sheathing leaves, and large, branching rootstocks. Flowers borne in dense, rigid, spike usually emerging from a spathe, these spikes dry and persist into late winter. Rootstocks are rich in starch. Distributed over entire United States.

Blue cattail — *Typha glauca*
Common cattail — *T. latifolia*
Narrowleaf cattail — *T. angustifolia*
Southern cattail — *T. domingensis*

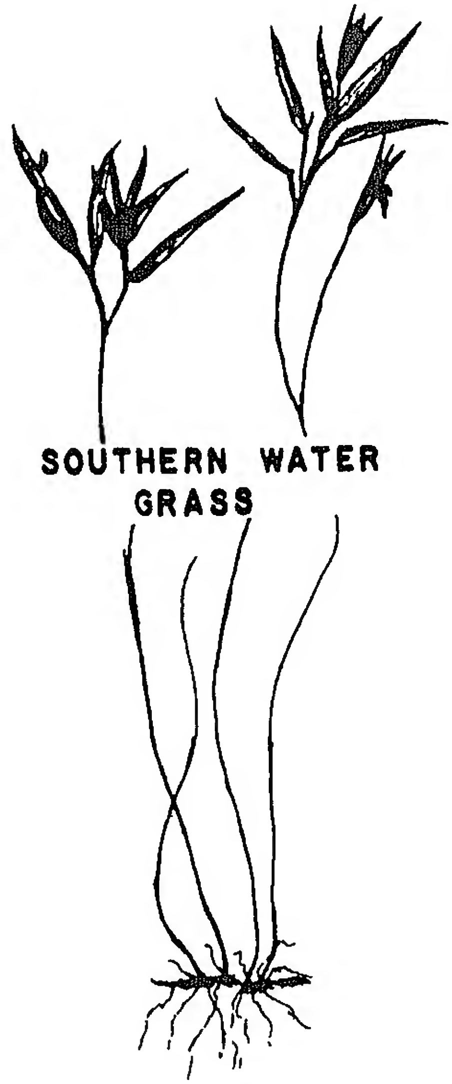


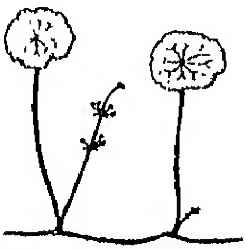
ʾarsley Family — *Umbelliferae.* Low perennial herbs with eping, stem-like rootstock often bearing small tubers. ıves round and peltate on erect petioles from rootstock, y be floating or emersed. Flowers small and white on erect iole. Grows over both North and South America.

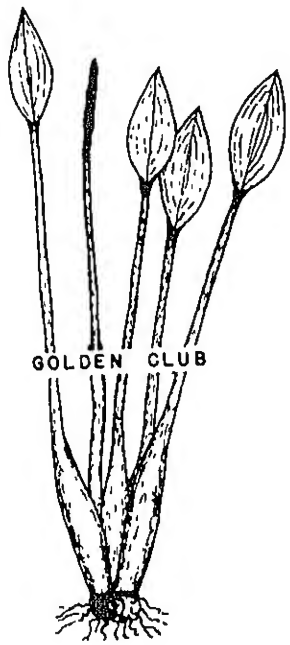
Pennywort — *Hydrocotyle* spp.

Arum Family — *Araceae.* Stout aquatic plants with alterıe, fleshy, clustered leaves, rootstock short, erect, with rous roots. Leaves lanceolate in shape and either erect or ating. Flowers borne in clusters at apex of stout stalk.

Golden club — *Oronthium aquaticum*




PENNYWORT



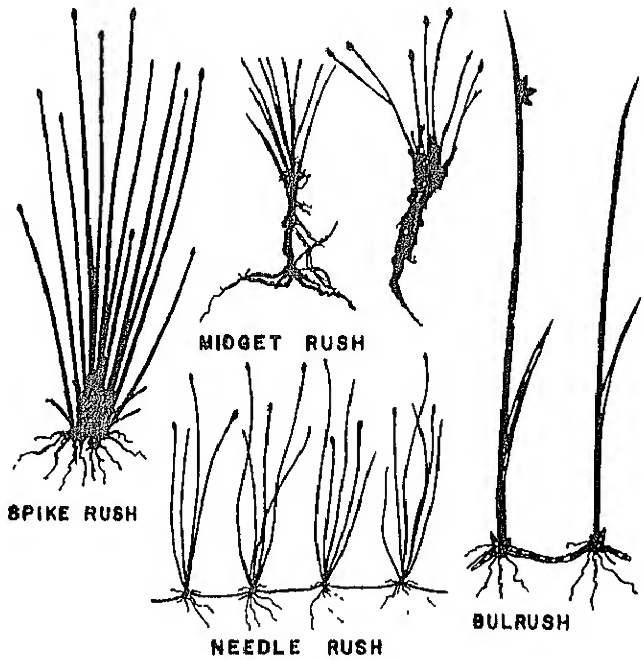
Grass Family — *Gramineae.* Plants with fibrous roots, ɔdose stems usually with hollow internodes and narrow, ırallel-veined, 2 ranked leaves composed of a sheath and ade. Seed heads are variable.

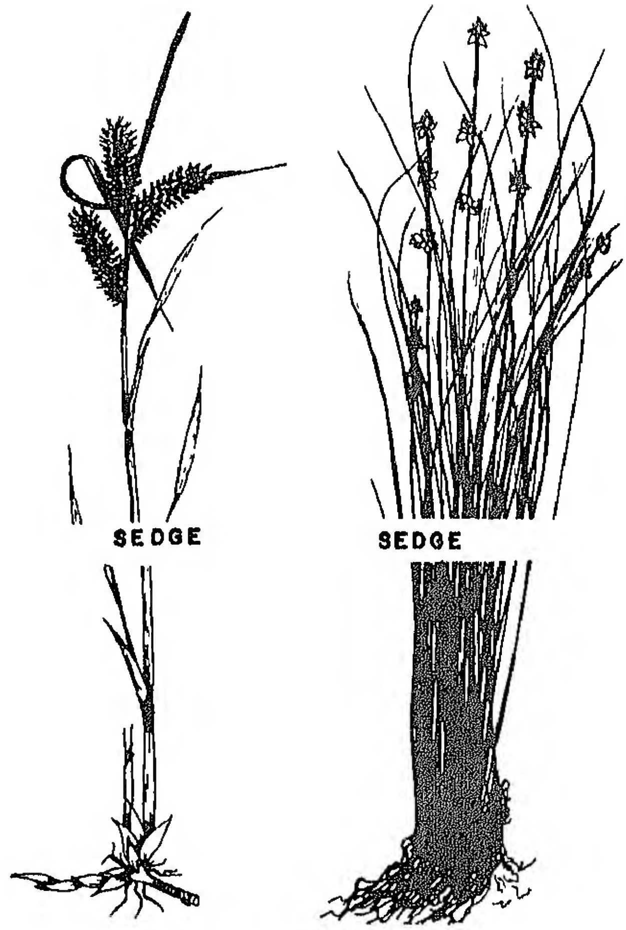
Giant cutgrass — *Zizaniopsis miliaceae*
Rice cutgrass — *Leersia oryzoides*
Southern cutgrass — *Leersia hexandra*
Giant reed — *Phragmites communis*
Cordgrass — *Spartina* spp.
Southern watergrass — *Hydrochloa caroliniensis*
Knotgrass — *Paspalum distichum*
Water paspalm — *Paspalum fluitans*
Paspalm — *Paspalum repens*
Maidencane — *Panicum hemitomon*
Paragrass — *Panicum purpurascens*
Torpedo grass — *Panicum repens*
Water managrass — *Glyceria fluitans*
Sawgrass — *Cladium jamaicense*

Southern watergrass grows from the moist shoreline into ʼaters up to 8 feet deep. The submersed portion of the plants re a mass of leafless stems with frequent rooting at the nodes. ʾhe emersed stems have tufts of leaf growths floating on or xtending above the water surface for 4 to 6 inches. Occurence rather infrequent, but it is potentially one of the more ıoxious plants.

Knotgrass grows from the moist shoreline into waters up to 2 feet deep. Its growth characteristics are very similar to Bermuda grass.

KNOT GRASS





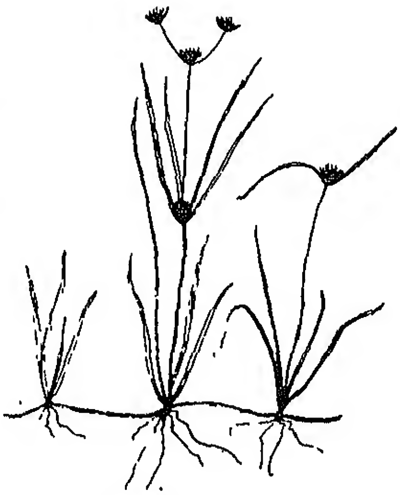
Sedge Family — *Cyperaceae.* Perennial plants having general appearance of grasses or rushes with fibrous roots and usually solid stems, often having creeping rootstocks. Leaves linear, parallel-veined, basal or alternate on stem, and with closed sheath. *Carex* has 3-sided stems, 3-ranked leaves that are often finely serrated on margin and lower midrib. Flowers borne in axils of scales (glumes) in spikelets.

Sedges — *Carex* spp.
Spikerushes — *Eleocharis* spp.
Flatsedges — *Cyperus spp.*
Bulrushes — *Scirpus* spp.

Sedges (*Carex* spp.) cause varying degrees of marginal infestation of all water areas throughout the United States. In certain situations their presence and abundance are such as to present serious problems in water movement, water loss through evaporation, and public health hazzards. The two forms shown represent the varied forms in this genus.

Rush Family — *Juncaceae.* Perennial plants with appearance of grasses, leaves flattened somewhat, sheathing at base, lower bladeless and reduced to mere sheaths. Creeping rootance of grasses, leaves somewhat flattened; sheathing at base; lower leaves bladeless and reduced to mere sheaths. Creeping rootstock, stems simple, pithy and hollow, often with partitions. Leaves often hollow. Flowers in terminal cluster. About 200 species grow in marshes and bogs, a few grow in water.

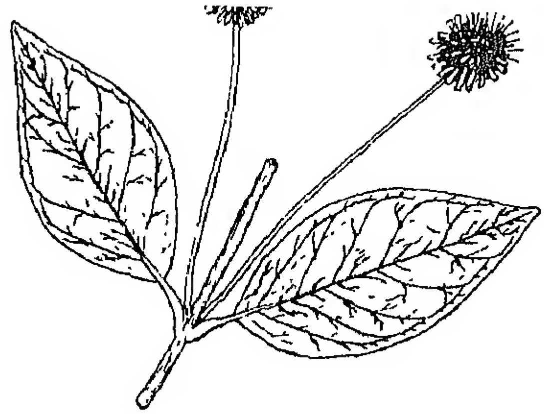
RUSH



RUSH

Madder Family — *Rubiaceae*. Large shrubs with leaves opposite or in 3's. Flowers in spherical heads on long bare stalks in axils of upper leaves. Mature fruits small brown balls. Grows on moist bank and into water a few inches in depth. Spread over eastern portion of United States.

Buttonbush — *Cephalanthus occidentalis*



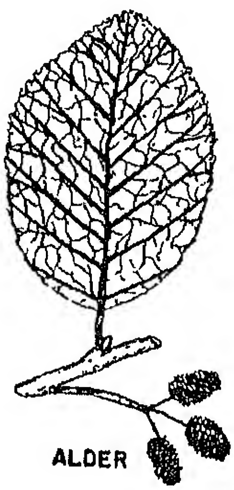
Willow Family — *Salicaceae*. Large shrubs or trees with simple alternate leaves that are several times as long as wide, usually toothed. Flowers in catkins that generally appear in spring before leaves. Distributed all over United States.

Willows — *Salix* spp.

Birch Family — *Betulaceae*. Large shrubs or small trees, leaves scattered, entire, heavily veined, toothed. Seed heads are small burs in clusters, similar to pine cones.

Alders — *Alnus* spp.

WILLOW



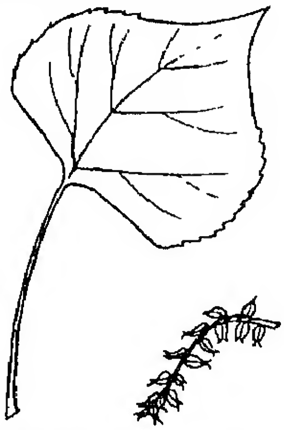
ALDER

Plains Cottonwood — *Populus sargentii*

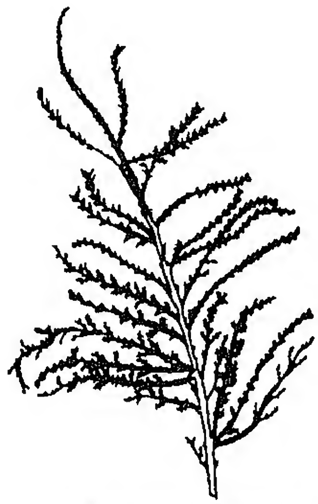
Large tree with gray bark, deeply furrowed. Leaves broadly oval, often wider than long, 3 to 4 inches long and wide, long-pointed, coarsely toothed with curved teeth, smooth, light green, shiny. Great Plains and Rocky Mountains.

Salt Cedar — *Tamarix pentandra*

A large shrub or small tree to 30 feet. Stems support slender, contorted branches with small scale-like leaves on the young branches. Flowers are borne in dense panicles developing from base to apex in individual racemes. Seeds are very small with slender hairs at the apex. Located in Southwest United States.



POPULUS SARGENTII



TAMARIX PENTANDRA

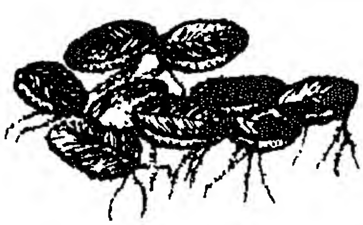
FLOATING PLANTS

This group has some species which are limited to their distribution while others are widespread throughout the world. Plants in this group have true roots and leaves, but instead of being anchored in soil they float about on the water surface. Bouancy of the plants is accomplished through modification of the leaf (including covering of leaf surface) and leaf petiole. Most species have extensive root systems which collect nutrients from the water medium. Most species are capable of reproducing at a rapid rate under favorable conditions, and are considered among the most obnoxious aquatics.

Major species are as follows:

Waterfern Family — *Salviniaceae.* Delicate, mosslike floating plants with small scalelike 2-lobed leaves; upper lobe aerial and lower lobe submersed. Reproduction by spores and by plant fragmentation. Plants green when young, turning pink, red, or brown with age. Plants confined to temperate and subtropical regions of United States.

Salvinia — *Salvinia rotundifolia*
Azolla — *Azolla caroliniana*



SALVINIA

AZOLLA

Pickerelweed Family — *Pontederiaceae.* Perennial or annual floating plants, with creeping rootstocks and large fibrous roots. Leaves in basal cluster, fleshy, ovate, and modified for boupancy. Flowers, a cluster borne on stalk above water. Seeds are produced, and they are viable under favorable conditions. Plants propagate vegetatively by sending out daughter plants on creeping rootstock. Confined to subtropical regions of the United States.

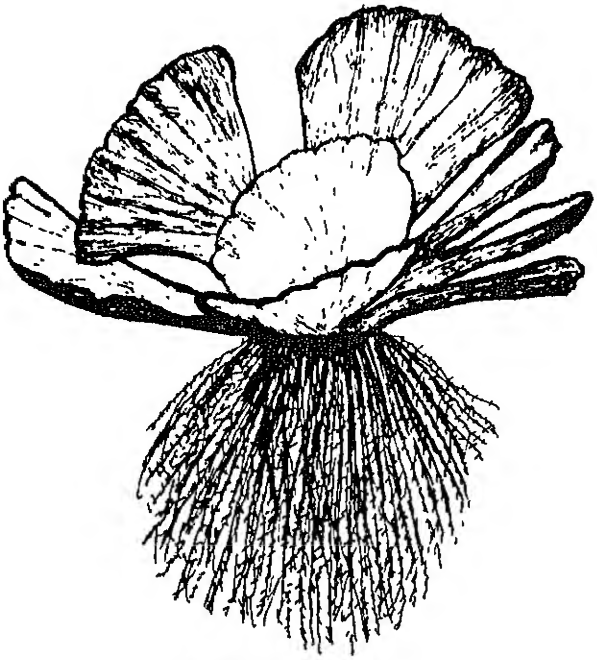
Waterhyacinth — *Eichhornia crassipes*

Waterhyacinth — A serious pest plant in water areas of subtropical and tropical areas throughout the world. Size of plants apparently determined by fertility of water environment and length of growing season. Causes problems in navigation, flood control and public health.

WATER HYACINTH

Arum Family — *Araceae.* Stout plants, mostly floating; leaves, hairy, fleshy and pliated, borne in rosettes from short stem bearing numerous adventicous branching roots. Propagation mainly vegetative by buds. Confined to subtropical areas of United States.

Waterlettuce — *Pistia stratioites*



WATERLETTUCE

Water Chestnut Family — *Hydrocaryaceae.* Annual aquatic herbs with long, cordlike, sparsely branching, submersed stems which arise from a nut. Leaves are of 3 kinds: linear, mostly alternate; submersed, finely dissected and 2 at each node; emersed rosette clustered with inflated rhombic blades. Seeds a 2 or 4 pronged nut borne on short stalk. If seeds are air dried they die. Native of Europe, Africa, and Asia, limited distribution in northeastern United States.

Water chestnut — *Trapa natans*

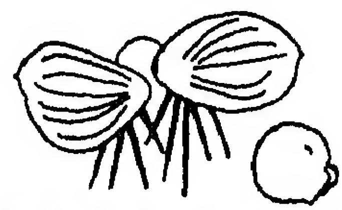
WATER CHESTNUT

Duckweed Family — *Lemnaceae.* Plants free floating, minute, with undifferentiated flattened or globular plant body (frond) and without definite stems or leaves. Fronds in colonies with or without roots. Reproduction is mainly vegetative by simple frond division.

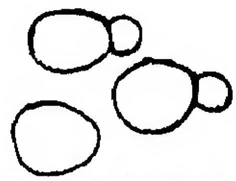
Common duckweed — *Lemna minor*
Giant duckweed — *Spirodela polyrhiza*
Watermeal — *Wolffia columbiana*

Duckweeds and watermeal usually occur as mixtures of several species. The growth of these plants in fresh waters is most abundant in areas protected from wind-wave action either by taller vegetation or shoreline configuration. Plants present serious problems by forming layer several inches thick on water surface. Such thick layers of plants are also very resistant to chemical control simply by physical inability to get chemicals on plants.

DUCKWEED



LARGE DUCKWEED



WATERMEAL

The following texts were used freely throughout the article to obtain good, simple descriptions as aids in identification:

Eyles, Don E., J. Lynne Robertson, Jr., and Garnet W. Jax. A Guide and Key to the Aquatic Plants of the Southeastern United States. 1944. Public Health Bulletin No. 286. 151 pp.

Palmer, C. Melvin. Algae in Water Supplies. 1959. Public Health Service Publication No. 657. 88 pp.

Prescott, G. W. How to Know the Fresh-Water Algae. 1954. Wm. C. Brown Company. 211 pp.

Fassett, Norman C. A Manual of Aquatic Plants. 1960. The University of Wisconsin Press. 405 pp.

Muenscher, Walter C. Aquatic Plants of the United States. 1944. Comstock Publishing Company. 374 pp.

CONTROL OF AQUATIC PLANTS

All methods for controlling aquatic plants fall into one of three categories: (1) mechanical, (2) biological, and (3) chemical. Each method has its own advantages and disadvantages depending on the method itself, the plant species, pond conditions, and the pond owner's objectives and preferences.

However, it should be remembered that it is nearly always easier to prevent aquatic plants from entering a pond than it is to get rid of them. The first priority in their control should be to make conditions unfavorable for their growth by having deep pond edges and highly fertile water. When used together, these two measures are the most effective and least expensive ways to control most aquatic plants.

Mechanical Methods

Pond edges should be constructed so they drop off to 2.5 to 3 feet or more as near the water's edge as possible. This not only discourages plant growth, but provides more habitat for adult game fish and more fishable areas from the banks.

A relatively small amount of hand labor can often be successful in controlling certain plants in ponds, if done before the plants have spread too much. A pond should be inspected at least once every few days during the growing season to see if any undesirable plants are appearing. Cattails, water lilies, arrowhead, water primrose, willow, and other plants can be easily controlled by hand pulling, if done when the first few appear.

Mowing along the pond edges can also help prevent certain grasses and other plants from spreading into the pond. This should be done as needed throughout the growing season. It is also very important for maintaining easy access everywhere along the banks for fishing.

Biological Methods

Winter fertilization can kill submersed plants in ponds, provided there is not a large volume of water (flow in a month which exceeds the volume stored) flowing through the pond. This method takes 4 or 5 months, but is safer and usually not as expensive as chemicals.

Begin in January or early February and fertilize as already described except for application; this time broadcast it from a boat over the plants, using about 200 pounds per acre. Repeat every two weeks until there is a heavy growth of single-filament algae.

The plants die in early summer due to the shading. They float to the surface, remain a few days, then sink to the bottom and quickly decompose. Fertilizer will cause the water to turn green after the plants decompose, since the growing plants will not be present to consume the fertilizer and keep the water clear.

This method of course should only be initiated in the winter and with submersed plants. Fertilizing ponds in spring or summer when submersed plants are already present will only increase the problem.

White amur may be stocked in ponds with plant problems. They should be stocked at the rate of 8-12 per acre. If adult bass or

catfish are already present, the white amur should be at least 8 inches long. However, these fish should not be relied upon to control cattails, waterlilies, water hyacinth, alligatorweed or bulrushes.

Chemical Methods

Chemicals should be used for aquatic plant control only as a last resort. Besides being expensive, they often decimate the basic fish food organisms (phytoplankton, zooplankton, and macroinvertebrates), and never constitute permanent solutions to plant control.

Chemicals can remove aquatic plants, but if the ecological conditions remain suitable, these plants will return. Putting a proper fertilization program into effect will often prevent the return of undesirable aquatic plants.

The following points should be realized before anyone recommends or uses herbicides in ponds:

1. The plants must be accurately identified. Early spring is the best time of the year to use herbicides, when plants begin to grow quickly, before seeds are developed.

2. Know which chemical works on the identified plant. Refer to Table 6 for recommended chemicals and rates for given plants.

3. Determine: primary use of pond water; acre-feet of water in the pond at time of treatment; approximate rate at which water is leaving the pond; and retention time for water in the pond.

4. The pond owner must understand the problem and the recommended solution. Insist that he read the label on the herbicide. He must understand that chemical control usually kills only 50 to 75 percent of the plant population and retreatment will often be necessary.

5. Fish can suffocate if large amounts of weeds are decaying in a pond and using oxygen faster than it can be added by photosynthesis, surface absorption, and other means. Therefore, no more than one-third of a heavily infested pond should be treated with chemicals at one time. Do not continue treatment until all vegetation from the prior treatment has thoroughly decomposed. Apply herbicides in the morning on sunny days.

The following comments on selected herbicides are from South Carolina Technical Note - Pesticides - 2 (Rev. 1) prepared by William J. Melven SCS Biologist in South Carolina. They should be used to help in deciding which chemical would be best to recommend among those listed in Table 6.

1. Copper Sulfate - for filamentous algae, scums and bluegreen algae. Copper sulfate (bluestone, blue vitrol) is probably the best and cheapest all around chemical for the control of most types of algae. It comes in crystals the size of rock salt, fine crystals, flakes or powder. The finer the material, the easier it is to dissolve in water. Powder placed in a sock suspended from a line on a pole can be an effective method of application. The sock can be left hanging in the water at one place and get a gradual spread

of the herbicide by wave and current action. Another method of application is to use the same arrangement as above except walk around the pond edge dragging the sock in the water around the algal mats.

Copper sulfate is more effective when the water temperature is about 60° F. The algae plants absorb the copper and their color fades from green to grayish white, indicating that the plants are in the process of dying. For heavy blooms or dense masses of filamentous algae, use lower rates (1 pound per surface acre) as a thinning method rather than as a complete kill.

2. Aquazine - for algae and rooted aquatics. The label for this herbicide states, "Use only in ponds which have little or no outflow after treatment". The label also says that a 1-year waiting time exists before water can be used for irrigation purposes. Results should occur in 14 days after treatment. Aquazine is toxic to shoreline plants, so this should be made known to the pondowner.

3. Diquat - is a wide spectrum herbicide for many different weeds. It works best when there is little or no outflow from the pond. It also does better in water that is above pH 6.5. DO NOT APPLY TO MUDDY WATER. Avoid creating muddy water during application. Do not apply where plants are covered with mud deposits. It is a highly recommended herbicide for duckweed. Use caution when treating duckweeds because they will die within 48 hours. Treat heavy growths about one-fourth of the area at one time and wait 10 to 14 days for the next treatment. The pond should be watched for any plants missed or washed ashore. These are to be retreated.

4. 2,4-D Granular - works good on rooted aquatics and in acid waters. April, May or June is the best time for treating rooted aquatics. The granular form has worked well to clear an area in a large pond or lake, when all the lake is not to be treated. For spot treatments a rate of 2 pounds per 430 square feet, evenly distributed over the weedbed, has been successful.

5. 2,4-D Liquid - for above water plants and along the edges of ponds.

6. Pennwalt Products - are also broad spectrum herbicides and algaecides. A mixture of one-half gallon of Hydrothol 191 and one-half gallon of Diquat has been successful in controlling Pithophora, the branched algae.

7. Copper Compounds - Cutrine and K-Lox are examples. These are algaecides that may be used when the water is extremely soft or is used where copper sulfate would be detrimental due to other uses of the water.

TABLE 5 - CHEMICAL CONTROL OF AQUATIC PLANTS 1/

Type and Kind of Aquatic Weed	Chemical	Rate or Concentration	Precautions and Remarks
ALGAE, PLANKTONIC Anabaena Microcystis Chlorella	Copper Sulfate (Bluestone)	0.1 to 0.5 ppm or 3/4 lb per surface acre	Place fine crystals of copper sulfate in cotton bags and suspend them from stakes or floats in the upper foot of water or use any method to give rapid and uniform dispersion. Re-treat as necessary. Safe in drinkable water.
	Copper, elemental (Cutrine-Plus)	0.6 gal* of Cutrine-Plus per acre-ft of water	Chemical should be diluted at least 9 to 1 to achieve uniform dispersion of algaecide in water. Cutrine-Plus may be harmful to fish in soft water.
	Aquazine	1.7 lb* per acre-foot of water for light infestation. 2.5-3.4 lb for moderate infestation	Mix powder with water to make a slurry and place in shallow water around the pond. Uniform dispersion is not necessary. Do not use treated water for irrigation, human or livestock consumption for 12 mo. Do not attempt spot treatment.
ALGAE, FILAMENTOUS FLOATING Spirogyra Anabaena Hydrodictyon Oedogonium	Copper sulfate (Bluestone)	0.5 ppm** in soft water (total hardness up to 50 mg/l) 0.5 - 1.0 ppm in hard water (total hardness above 50 mg/l)	The use of copper sulfate in soft water can kill fish. Soft water should be limed before applying copper sulfate. Copper sulfate is safe in potable water.
	Copper, elemental (Cutrine-Plus)	0.6 gal* of Cutrine-Plus per acre-ft of water	Dilute 9 to 1 to achieve uniform dispersion of the algaecide.
	Aquazine	4.2 lb* per surface acre	Same as for planktonic algae. Do not use water for irrigation, human or livestock consumption for 12 mo.
	Hydrothol 191	0.6 to 2.2 pt* per acre-ft (0.05 to 0.2 ppm)	Apply as uniform surface spray or inject under water. Fish may be killed by rates in excess of 0.3 ppm.
	Hydrothol 191 Granular	3 lb to 11 lb* per acre-ft (0.05 to 0.2 ppm)	Broadcast evenly over plants. Fish may be killed with rates in excess of 0.3 ppm.
	Hydout	1.5 to 5.5 lb* Hydout per acre-ft (0.05 to 0.2 ppm)	Broadcast evenly over plants. Fish may be killed with rates in excess of 0.3 ppm.

1/ 1980 Agricultural Chemicals Handbook, Clemson University Cooperative Extension Service.
*Rates are for formulated products not active ingredients.
**1 ppm = 2 lbs 11 oz (2.7 lbs or 43 oz) per acre-foot; therefore, 0.1 ppm = 4.3 oz. per acre-foot.

Type and Kind of Aquatic Weed	Chemical	Rate or Concentration	Precautions and Remarks
ALGAE, FILAMENTOUS BOTTOM-GROWING Pithophora Cladophora	Cutrine-Plus Granular	60 lb* per surface acre	Granular Cutrine can be used to spot treat. Cyclone seeders are useful for applying granular. Avoid breathing dust. Pithophora and other bottom-growing algae are extremely difficult to control.
	Hydrothol 191	0.6 to 2.2 pt* per acre-ft (0.05 to 0.2 ppm)	Apply as spray or inject under water. Pithophora may require 0.2 ppm or higher rates. Fish may be killed at rates higher than 0.3 ppm.
	Hydrothol 191 Granular	3 lb to 11 lb* acre-ft (0.05 to 0.2 ppm)	Broadcast evenly over plant material. Pithophora may require 0.2 ppm or higher rates. Fish may be killed at rates higher than 0.3 ppm.
	Hydout	1.5 lb to 5.5 lb* per acre-ft (0.05 to 0.2 ppm)	Broadcast evenly over plants. Pithophora may require 0.2 ppm or higher rate. Fish may be killed at rates higher than 0.3 ppm.
ALGAE, ATTACHED, WEED-LIKE Chara Nitella	Cutrine-Plus Granular	60 lb* per surface acre of water	Apply when plants are young and uncalcified. Follow label directions. Cutrine may be harmful to fish in soft water.
	Cutrine-Plus Liquid	1.2 gal* per acre-ft	Use when water is 3 ft deep or less. Dilute 9 to 1 with water. Cutrine may be harmful to fish in soft water.
	Aquazine	4.25 lb*	Mix powder with water to make a slurry and place in shallow water around the pond. Uniform dispersion is not necessary. Do not use treated water for irrigation, human or livestock consumption for 12 months. Do not attempt spot treatment.
	Hydrothol 191	0.6 to 2.2 pt* per acre-ft (0.05 to 0.2 ppm)	Check label for calculating rates and for precautions.
	Hydrothol 191 Granular	3 lb to 11 lb* per acre-ft (0.05 to 0.2 ppm)	
	Hydout	1.5 lb to 5.5 lb* per acre-ft (0.05 to 0.2 ppm)	

* Rates are for formulated products not active ingredients.

Type and Kind of Aquatic Weed	Chemical	Rate or Concentration	Precautions and Remarks
FLOATING PLANTS Duckweed Waterfern	Diquat	1 gal* per surface acre	Foliar spray or inject into non-flowing water and non-muddy water. Do not use treated water for irrigation, livestock, fishing, swimming, or drinking for 10 days. Use higher rate as recommended on label for late season application.
	2,4-D amine 69.9% salts or low-volatile esters Weed-Rhap LV-4D	1 gal* per acre or 2 to 4 lb 100 gal diluent	Spray foliage when weeds are growing. Include detergent or 1 pt emulsifier. Repeat every 4 to 6 weeks. Use higher rate as recommended on label for late season application.
EMERGENT PLANTS Alligator Weed	2,4-D amine salts or low-volatile esters Weed-Rhap LV-4D	2 to 4 lb 100 gal diluent	Spray to uniformly wet foliage when weeds are growing. Include 10 gal fuel oil and 1 pt of emulsifier. Alligator weed can be killed back but will quickly re-establish itself.
Spikerush or Hairgrass	Diquat	2 lb per surface acre or 1 gal* per surface acre	Inject or apply as evenly as possible and mix pond water as much as possible. Spikerush is extremely difficult to control.
American lotus, waterlily, pickerel weed, yellow cowlily, watershield	2,4-D (granular) Aqua-Kleen (29.0%) Weedtrine-II-(30.22%)	30-40 lb per surface acre 150-200 lb* per surface acre 100 lb per surface acre	Broadcast at early stage of weed growth using cyclone seeder or other spreader. Water pH of 8.0 or above may reduce effective action of this herbicide.
Arrowhead Smartweed	2,4-D (Isooctylester)	8 lb per surface acre	Spray on foliage, follow label instructions.
Frogbit Pennywort	2,4-D (Dimethylalkylamine salt)	4 lb per surface acre	Spray on foliage, follow label instructions.
SUBMERGED PLANTS Watermilfoil	2,4-D (granular) Weedtrine II Aqua-Kleen Rhodia 2,4-D	20 lb per surface acre 100 lb* per surface acre 100 lb* per surface acre 100 lb* per surface acre	Broadcast over surface of weeds before mid-summer. Broadcast over surface of weeds before mid-summer. Broadcast over surface of weeds before mid-summer. Broadcast over surface of weeds before mid-summer.

*Rates are for formulated products not active ingredients.

Type and Kind of Aquatic Weed	Chemical	Rate or Concentration	Precautions and Remarks
	Endothall		
	Aquathol Granular	50 lb* to 80 lb* per acre-ft	Broadcast over surface using higher rates in late season.
	Aquathol "K"	1 to 2 gal* per acre-ft	Spray or inject using higher rates late in season.
	Hydrothol 191 Hydrothol 191 Granular Hydout		Due to the toxicity to fish, the use of these three products for submerged aquatics is suggested only by commercial applications. Refer to label for rates, application instructions, and precautions for specific plants.
	Aquazine	3.4 to 6.8 lb* per acre-ft	Use higher rates for heavy infestations and late in the season. Note restrictions on use of treated water.
	Diquat	1 to 2 gal* per surface acre	Follow label instructions for application during early or late season. Use higher rates for heavy infestations, late season treatment, and/or mixed plant species. Do not inject into muddy water.
Cabomba	Diquat	1 to 2 gal* per surface acre	Inject, following same instructions as above.
	Aquazine	8.5 lb* per acre-ft	Apply according to label; note 1-year restriction on use of treated pond by cattle.
Bladderwort	2,4-D granular		
	Rhodia 2,4-D Gran 20	100 to 150 lb* per surface acre	Broadcast over weeds before mid-summer - may cause off-flavor in fish.
	Aqua-Kleen	100 to 150 lb* per surface acre	Broadcast over weeds before mid-summer.
	Diquat		
	Weedtrine D	5 to 10 gal* per surface acre	Use higher rates for heavy infestations and/or late season application according to label directions.
	Ortho Diquat	1 to 2 gal* per surface acre	
Waterstargrass	Endothall		
	Aquathol "K"	1.3 to 1.9 gal* per acre foot of water.	Use higher rates for heavy infestation and/or late season application.
	Aquathol Granular	54 lb to 84 lb per acre ft (2 to 3 ppm)	Broadcast evenly over plants. Treat heavily infested ponds in sections.

*Rates are for formulated products not active ingredients.

Type and Kind of Aquatic Weed	Chemical	Rate or Concentration	Precautions and Remarks
Widgeongrass	Diquat	0.5 ppm active ingredients	Inject into non-flowing water.
Parrotsfeather	2,4-D granular		
	Weedtrine II	100 lb* per surface acre	Broadcast over weed surface.
	2,4-D Liquid		
	Weed-Rhap LV-4D	2-1/2 to 4-1/2 pt* per surface acre	Mix with 50 to 100 gal water and a good surfactant spray over weeds.
Coontail	2,4-D (granular)		
	Aqua-Kleen	150 to 200 lb* per surface acre	Apply evenly over infested area before mid-summer.
	Rhodia 2,4-D Gran 20	200 lb* per surface acre	Apply evenly over infested area before mid-summer. May cause off-flavor in fish.
	Weedtrine II Granular	100 lb* per surface acre	Apply evenly over infested area before mid-summer.
Common Elodea	Diquat		
	Ortho Diquat	2 gal* per surface acre	Apply by pouring or injecting formulated product or solution according to directions on label. Do not inject into muddy water.
	Weedtrine D	10 gal per surface acre	
	Endothall		
	Aquathol K	1 to 2 ppm or 0.6 to 1.3 bal* per acre-ft of water	Spray or inject using higher rates later in season.
	Aquathol granular	27 lb* to 50 lb* per acre-ft of water	Broadcast over surface of infested area.
	Hydrothol 191 Hydrothol 191 Granular Hydout		Due to toxicity of fish the use of these formulations for submerged aquatic plants is suggested only by commercial applicators. Refer to the label for rates and precautions.
Naiads	Diquat		
	Ortho Diquat	1 gal* per surface acre	Pour or inject formulated product or solution of product according to label recommendations. Do not use in muddy water.
	Weedtrine D	5 gal* per surface acre	
	Aquazine	3.4 to 6.8 lb* per acre-ft of water	Apply according to label; note 1-year restriction on use of treated water for cattle.
	Cutrine-Plus (granular)	60 lb* per surface acre	Apply early in season.

Type and Kind of Aquatic Weed	Chemical	Rate or Concentration	Precautions and Remarks
	Endothall Hydrothol 191 Hydrothol 191 Granular Hydout		Due to toxicity of fish the use of these formulations for submerged aquatic plants is suggested only by commercial applicators. Refer to the label for rates and precautions.
	2,4-D granular	200 lb per acre	Broadcast over weedbed.
Potamogeton spp. (pond weeds)	Aquazine	3.4 to 6.8 lb* per acre-ft	Apply according to label; note 1-year restriction on use of treated water for cattle.
	Endothall Aquathol K	0.6 gal to 1.9 gal* per acre-ft (1 to 3 ppm)	Spray or inject below water. Distribute as evenly as possible.
	Aquathol Granular	27 lb to 81 lb* per acre-ft (1 to 3 ppm)	Broadcast evenly over plants.
	Hydrothol 191 Hydrothol 191 Granular Hydout		Due to the toxicity of fish the use of these formulations for submerged aquatic plants is suggested only by commercial applicators. Refer to the label for rates and precautions.
	Diquat	2 gal per surface acre	Pour or inject formulated product or solution of product according to label recommendations. Do not use in muddy water.
AQUATIC GRASSES (ditches with flowing water and impoundments) sawgrass, southern watergrass, cutgrass, giant foxtail, giant reed, maidencane, paragrass, torpedograss, water paspalum	None registered for use in flowing water or impoundments. Controlled by underwater mowing, water level manipulation, or draining impoundment, drying bottom and using nonresidual chemicals labeled for pond banks and drainage ditches with non-flowing water.	None	Since there are no aquatic herbicides registered for the control of grasses in flowing water or impoundments, mechanical methods must be used to remove them.
Emergent cattail	Diquat	1 oz* diquat per 3.0 gal water and 1.0 oz of wetting agent (detergent)	Spray on foliage before seedhead is formed to prevent reseeding.
Bulrushes	2,4-D (low-volatile esters)	4.0 to 6.0 lb per acre with surfactant	Apply in 1:20 oil-water emulsion at 150 to 300 gal per acre. Repeat applications as needed.

*Rates are for formulated products not active ingredients.

GENERAL RESTRICTIONS ON USE OF TREATED WATER (NUMBER OF DAYS)

Common Name	Chemical Name	Amount of Active Ingredients	Conc. ppm	Human: Drinking	Human: Swimming	Human: Fish Consumption	Animal: Drinking	Irrigation: Turf	Irrigation: Food Crops	Irrigation: Forage
Cutrine-Plus Liquid	Copper Alkanolamine Complex	9%		0	0	0	0	0	0	0
Cutrine-Plus Granular	Copper Alkanolamine Complex	3.7%		0	0	0	0	0	0	0
2,4-D Liquid Ester	2,4-dichlorophenoxyacetic acid	4 lb per gal		*	1	3	*	3	*	*
2,4-D Granular Ester	2,4,5-trichlorophenoxyacetic acid	20% per lb		*	1	3	*	3	*	*
Diquat	1:1-ethylene-2:2-dipridylium dibromide	2 lb of cation per gal		10	10	10	10	10	10	10
Aquathol K	Dipotassium salt of endothall	4.23 lb per gal		7	1	3	7	7	7	7
Aquathol Granular	Dipotassium salt of endothall	10.1%		7	1	3	7	7	7	7
Hydrothol 191	Mono (N,N-dimethylalkylamine) salt of endothall	53.0%	0.3	7	7	3	7	7	7	7
			3.0	14	14	3	14	14	14	14
Hydrothol 191 Granular	Mono (N,N-dimethylalkylamine) salt of endothall	11.2%	0.3	7	7	3	7	7	7	7
			3.0	14	14	3	14	14	14	14
Hydout	Mono (N,N-dimethylalkylamine) salt of endothall	22.4%	0.3	7	7	3	7	7	7	7
			3.0	14	14	3	14	14	14	14
Copper Sulfate	Copper Sulfate (Pentahydrate)	99%		0	0	0	0	0	-	0
Aquazine	Simazine:2-chlora-4,6-bis (ethylamino) -s-triazine	80%		360	0	0	360	360	360	360

* Restrictions were not available; consult chemical manufacturer, county extension agent, or state plant pest regulatory service.
**Care should be taken to prevent contamination of water. Presently no approval for aquatic use is contained on the manufacturer's label.

As anyone who is familar with herbicides knows, few of these chemical compounds are inexpensive. The following costs were taken from a 1980 catalog of an Arkansas farm supply firm to show the relative costs of certain herbicides used for aquatic plant control.

TABLE 6 - RELATIVE COSTS OF AQUATIC HERBICIDES

Chemical	Package Size	Price Per Pound or Gallon	Container Price
Copper Sulfate (powder)	100 lb. bag	$ 0.615	61.50
Copper Sulfate (crystal)	100 lb. bag	0.595	59.50
Aquathol K Liquid	5 gal. can	24.95	124.25
Aquathol K Granular	50 lb. bag	0.95	47.50
Casoron AQ 10% Granular	50 lb. bag	2.85	142.50
Diquat	1 gal. jug	58.95	58.95
2, 4-D Amine	55 gal. drum	12.15	668.25
2, 4-D Amine	30 gal. drum	12.30	369.00
2, 4-D Amine	5 gal. can	12.50	62.50
2, 4-D Amine	1 gal. can	12.75	12.75
Aqua-Kleen Granular	50 lb. bag	0.95	47.50
Cutrine-Plus	1 gal. bottle	24.50	24.50
Cutrine-Plus	5 gal. can	23.50	117.50
Aquazine Algaecide	5 lb. bag	3.95	19.75
Aquazine Algaecide Case	10 5 lb. bags	3.85	192.50

PESTICIDES PRECAUTIONS

The following precautions should be conveyed to the users of pesticides. Pesticides used improperly can be injurious to man, animals, and plants. Follow directions and heed all precautions on labels of their containers.

Store pesticides in original containers under lock and key - out of the reach of children and animals - and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides as you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill, or crush and bury them in a level, isolated place.

Always read and follow carefully the directions for the specific use to be made of the pesticide.

TABLE 7 - EQUIVALENTS

Length		
Centimeter	=	0.3937 inch
Meter	=	3.28 feet
Meter	=	1.094 yards
Kilometer	=	0.621 statute mile
Kilometer	=	0.5400 nautical mile
Inch	=	2.54 centimeters
Foot	=	0.3048 meter
Yard	=	0.9144 meter
Statute mile	=	1.61 kilometers
Nautical mile	=	1,852 kilometers

Area		
Sq. centimeter	=	0.155 sq. inch
Sq. meter	=	10.76 sq. feet
Sq. meter	=	1.196 sq. yards
Hectare	=	2.47 acres
Sq. kilometer	=	0.386 sq. mile
Sq. inch	=	6.45 sq. centimeters
Sq. foot	=	0.0929 sq. meter
Sq. yard	=	0.836 sq. meter
Acre	=	0.405 hectare
Sq. mile	=	2.59 sq. kilometers

Volume		
Cu. centimeter	=	0.0610 cu. inch
Cu. meter	=	35.3 cu. feet
Cu. meter	=	1.308 cu. yards
Cu. inch	=	16.39 cu. centimeters
Cu. foot	=	0.0283 cu. meter
Cu. yard	=	0.765 cu. meter

Capacity		
Milliliter	=	0.0338 U.S. fluid ounce
Liter	=	1.057 U.S. liq. quarts
Liter	=	0.908 U.S. dry quart
U.S. fluid ounce	=	29.57 milliliters
U.S. liq. quart	=	0.946 liter
U.S. dry quart	=	1.101 liters

TABLE 7 - EQUIVALENTS (Continued)

Grams	Gr. or Oz.	Ounces	Kilo-grams	Kg. or Lb.	Pounds	Metric Tons	Mt. or T.	Net Tons (2,000 (Lbs.)
28.35	1	0.0352	0.454	1	2.205	0.9072	1	1.1023
56.70	2	0.0704	0.907	2	4.409	1.8144	2	2.2046
85.05	3	0.1056	1.361	3	6.614	2.7216	3	3.3069
113.40	4	0.1408	1.814	4	8.819	3.6288	4	4.4092
141.75	5	0.1760	2.268	5	11.023	4.5360	5	5.5115
170.10	6	0.2112	2.722	6	13.228	5.4432	6	6.6138
198.45	7	0.2464	3.175	7	15.432	6.3504	7	7.7161
226.80	8	0.2816	3.629	8	17.637	7.2576	8	8.8184
225.15	9	0.3168	4.082	9	19.842	8.1648	9	9.9207
283.50	10	0.352	4.536	10	22.046	9.072	10	11.023

Hec-tares	Ha. or Ac.	Acres	Liters	L. or Gal.	Gallons	Kilo-grams/ Hectares	Kg./Ha. or Lbs./Ac.	Pounds /Acre
0.405	1	2.471	3.785	1	0.264	1.12	1	.891
0.809	2	4.942	7.571	2	0.528	2.24	2	1.782
1.214	3	7.413	11.356	3	0.793	3.36	3	2.673
1.619	4	9.884	15.142	4	1.057	4.48	4	3.564
2.023	5	12.355	18.927	5	1.321	5.60	5	4.455
2.428	6	14.826	22.712	6	1.585	6.72	6	5.346
2.833	7	17.297	26.498	7	1.849	7.84	7	6.237
2.237	8	19.769	30.283	8	2.114	8.96	8	7.128
3.642	9	22.240	34.069	9	2.378	10.08	9	8.109
4.047	10	24.711	37.854	10	2.642	11.20	10	8.910

TABLE 7 - EQUIVALENTS (Continued)

Ton (Metric)/ Hectares	Ton (M)/Ha. or Ton (E)/Ac.	Ton (English)/ Acre
2.24	1	.446
4.48	2	.892
6.72	3	1.338
8.96	4	1.784
11.20	5	2.230
13.44	6	2.676
15.68	7	3.122
17.92	8	3.568
20.16	9	4.014
22.40	10	4.460

Square Meters	Square M. or Ft.	Square Feet
0.093	1	10.764
0.186	2	21.528
0.279	3	32.292
0.372	4	43.056
0.465	5	53.820
0.557	6	64.584
0.650	7	75.348
0.743	8	86.112
0.836	9	96.876
0.929	10	107.64

Square Meters	Square M. or Yd.	Square Yards
0.836	1	1.196
1.672	2	2.392
2.508	3	3.588
3.344	4	4.784
4.181	5	5.980
5.017	6	7.176
5.853	7	8.372
6.689	8	9.568
7.525	9	10.764
8.361	10	11.96

Kilo-grams/ Meter	Kg./M or Lb./Ft.	Pounds Foot
1.488	1	0.672
2.976	2	1.344
4.465	3	2.016
5.953	4	2.688
7.441	5	3.360
8.929	6	4.032
10.417	7	4.704
11.906	8	5.376
13.394	9	6.048
14.882	10	6.720

Kilo-grams Square Meter	Kg./Sq. M. or Lb./Sq. Ft.	Pounds/ Square Foot
4.883	1	0.205
9.765	2	0.410
14.648	3	0.614
19.530	4	0.819
24.413	5	1.024
29.295	6	1.229
34.178	7	1.434
39.060	8	1.638
43.943	9	1.843
48.825	10	2.048

Kilo-gram/ Cubic Meter	Kg./Cu. M. or Lb./Cu. Ft.	Pounds/ Cubic Foot
16.019	1	0.062
32.038	2	0.125
48.058	3	0.187
64.077	4	0.250
80.096	5	0.312
96.115	6	0.374
112.134	7	0.437
128.154	8	0.499
144.173	9	0.562
160.192	10	0.624

TABLE 7 - EQUIVALENTS (Continued)

From/To	Ton(M)/Ha.	Ton(E)/Ac.	Kg./Ha.	Lb./Ac.	Q./Ha.
Ton (Metric)/Hectare	1	.446	10^{3}	891.	10
Ton (English)/Acre	2.24	1	2,240	2,000	22.4
Kilogram/Hectare	10^{-3}	4.46×10^{-4}	1	.891	.01
Pound/Acre	1.12×10^{-3}	5×10^{-4}	1.12	1	.0112
Quintal/Hectare	.10	.0446	100	89.1	1
Kg./Ha./Cm. to Lbs./Ac./In.	2.263				
Lbs./Ac./In. to Kg./Ha./Cm.	0.4413				

1 acre-foot = 43,560 cubic feet
2,718,144 pounds of water
326,000 gallons of water

1 cubic foot = 7.5 gallons
62.4 pounds of water

1 gallon = 8.34 pounds of water
1 ppm 2.7 pounds per acre foot of water
0.1 ppm 4.3 ounces (2.7 x 16 oz. ÷ 10)
1 ppm 1 milligram per liter
1 kilogram 1000 grams

Solution Percentages

For 1 percent add:

38 grams per gallon of water
1.3 ounces per gallon of water
10 grams per liter of water
38 cubic centimeters per gallon of water
10 cubic centimeters per liter of water

Temperature Conversion

(Celsius x 9/5) + 32^{0} = Fahrenheit
(Fahrenheit - 32^{0}) x 5/9 = Celsius

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